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MANUAL OF ZOOLOGY

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MANUAL OF ZOOLOGY

FOR THE USE OF STUDENTS

WITH A GENERAL INTRODUCTION ON THE PRINCIPLES OF ZOOLOGY

BY

HENRY ALLEYNE NICHOLSON

M.D., D.Sc., Ph.D. (Gött.), F.L.S., F.G.S.

REGIUS PROFESSOR OF NATURAL HISTORY
IN THE UNIVERSITY OF ABERDEEN

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PREFACE TO THE SEVENTH EDITION.

THE revision of a book dealing with a subject so progressive as Zoology is, under the best of circumstances, a difficult undertaking. In the present instance, the changes which appeared to the author to be needful, if a satisfactory result was to be obtained, were so numerous that it did not seem possible that they could be covered by anything that would ordinarily be understood under the head of a mere "revision." While, therefore, the general plan of the original work has been retained, the present edition has been wholly recast, and, with the exception of some small portions, entirely rewritten. The work in its present form may thus be regarded as essentially a new one. A considerable number of fresh illustrations have also been added. By these, and by the changes which have been effected in the text, it is hoped that the present edition, in spite of the imperfections which it doubtless possesses, will be found to have been rendered more suitable than its predecessors for the use of students of natural history.

To Mr Lydekker the author is much indebted for the

indication of errors, and the suggestion of improvements, with regard to the Vertebrates generally.

Lastly, the author regrets that the portion of the work dealing with the Invertebrates had passed through the press before the publication of vol. xvii. and the subsequent volumes of the Reports of the Challenger Expedition.

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MANUAL OF ZOOLOGY.

GENERAL INTRODUCTION.

I. Definition of Biology and Zoology.

Natural History, strictly speaking, and as the term itself implies, should be employed to designate the study of all natural objects indiscriminately, whether these are endowed with life, or exhibit none of those incessant vicissitudes which collectively constitute vitality. So enormous, however, have been the conquests of science within the last century, that Natural History, using the term in its old sense, has of necessity been divided into several more or less nearly related branches.

In the first place, the study of natural objects admits of an obvious separation into two primary sections, of which the first deals with the phenomena presented by the inorganic world, whilst the second is occupied with the investigation of the nature and relations of all bodies which exhibit life. The former department concerns the geologist and mineralogist, and secondarily the naturalist proper as well; the latter department, treating as it does of living beings, is properly designated by the term *Biology* (from βίος, *life*, and λόγος, a *discourse*). Biology, in turn, may be split up into the sciences of Botany and Zoology, the former dealing with plants, the latter with animals; and it is really *Zoology* alone which is nowadays understood by the term Natural History. It should also be borne in mind that the science which deals with those forms of life which have existed during previous periods of the earth's history to the present, and which is usually designated

by the separate title of *Palæontology*, is, in all strictness, part and parcel of *Biology* proper, and has no relations but indirect ones with Geology. As living beings are divisible into animals and plants, so Palæontology falls into the two branches of Palæozoology and Palæobotany, of which the former is inseparably united with Zoology or Natural History, while the latter is part of Botany as ordinarily understood. It is with animals and plants as *organisms* that Palæontology has to deal, and the methods of palæontological inquiry are those employed by the zoologist and the botanist. We must therefore assign to Biology a considerably wider domain than that which has been allowed to it by the earlier workers in the department of Natural History.

It will be obvious, then, that in the attempt to determine the limits and scope of Biology, we are brought at the very threshold of our inquiry to the question, What are the differences between dead and living bodies? Before considering this point, however, it will be advisable to discuss briefly the characters which in a general way distinguish what are known as "organic" from "inorganic" bodies.

2. Differences between Organic and Inorganic Matter.

The terms "organic" and "inorganic," as applied to the various kinds of matter of which the universe is composed, had, to begin with, a very definite signification; the latter being applied to all those forms of matter which exist independently of the operation of living beings, whilst all kinds of matter produced by the vital chemistry of living beings were grouped together under the former title. "Inorganic" Chemistry, for example, was that department of chemical science which dealt with the latter class of bodies; while "Organic" Chemistry concerned itself wholly with those of the former group. Even at an early period, however, some confusion was created by the necessity of employing the term "organic" for accumulations of inorganic matter which had at one time entered into the composition of living beings. Thus, limestone is in one sense inorganic, since carbonate of lime, of which it is formed, occurs in nature quite independently of the operation of living beings. In another sense, however, most limestones are organic, since the lime of which they are composed has been in the main derived from the skeletons of animals or plants.

At the present day, the term "organic" has been widely extended in its significance by the wonderful discoveries of modern science; and "Organic Chemistry," as it is still commonly called, embraces a much more extensive field of investigation than would be afforded merely by those substances which are actually manufactured by living beings. In addition, namely, to substances like starch, sugar, fat, and other bodies which are produced solely by the living organism, and which cannot at present be artificially generated, we embrace under the head of "Organic Chemistry" a vast number of compounds which are not produced by living beings, but are artificially manufactured by the chemist in the laboratory. These compounds are derived by various chemical processes from strictly organic substances, which are in reality the product of vital action, and they might therefore be appropriately called "secondary organic bodies."

The link between the primary and secondary organic bodies is afforded by substances such as *urea*, which is one of the most characteristic of animal products, and which was for a long time unknown except as resulting from animal life. It is now known, however, as first showed by Wöhler, that urea is in chemical composition identical with cyanate of ammonia, a substance which can be manufactured on any desired scale in the laboratory. There are many other compounds which were originally only known as the products of vital action, but which have now been produced by synthetic processes in the laboratory of the chemist; and future researches are likely to add largely to the number of these.

It need hardly be added, that the term "organic," as applied to any substance, in no way relates to the presence or absence of *life*. The materials which compose the living body are, of course, "organic" in the main, but they are equally so after death has occurred—at any rate for a certain time—and some of them continue to be so for an indefinite period after life has departed. Sugar, for example, is an organic product; but in itself it is of course dead, and it retains its stability after the organism which produced it has lost all vitality.

The following are the more important characters which distinguish the various organic substances, whether directly produced by living beings, or secondarily formed by chemical processes of different kinds: (1) Inorganic bodies are composed of a large number of elements; and these elements are either simple and uncombined, or they are associated into simple compounds, which rarely consist of more than two or three elements united, and are therefore called "binary" or

"ternary" compounds. On the other hand, organic bodies are composed of few elements, and these are always combined. Indeed there are only four principal organic elements —namely, carbon, hydrogen, oxygen, and nitrogen; and of these the first is so much the most important, that Organic Chemistry has been appropriately termed the "Chemistry of Carbon." Furthermore, the combinations of the elements in organic compounds are complex, the resulting substances being mostly "ternary," "quaternary," or "quinary" compounds; and there is generally a larger number of atoms or equivalents of the combining elements than is usually the case among inorganic bodies. Thus, carbonate of lime consists of no more than one atom of calcium, one of carbon, and three of oxygen. On the other hand, albumen, which may be taken as a typical organic substance, consists of 144 atoms of carbon, 110 atoms of hydrogen, 18 atoms of nitrogen, 42 atoms of oxygen, and 2 atoms of sulphur. Hæmoglobin (the red colouring-matter of the blood), again, is stated by Thudichum to consist of no less than 1875 atoms of no more than six elements. Iron, however, exists in the blood, not improbably in its elemental condition; and copper has been detected in the liver of the mammalia, and largely in the red colouring-matter of the feathers of certain birds, in the latter instance being in a condition of loose chemical combination.

(2.) As the result of the large number of atoms which enter into the composition of organic bodies, we find that substances of this class are singularly *unstable*—the stability of all chemical combinations, even amongst inorganic bodies, generally decreasing in direct proportion to the increased number of atoms associated in the compound. Organic bodies, being composed of much larger aggregations of atoms than inorganic, are proportionately more unstable; and this instability is increased by the fact that many organic substances contain nitrogen, an element of feeble and undecided affinities, and also by the fact that all those which are of natural and normal occurrence in the living body, are in this state more or less completely permeated with water.

Hence, the primary organic substances, such as enter directly into the composition of living beings, are so unstable that we usually speak of them as decomposing or breaking up "spontaneously," when removed from the influence of the living organism. So long as they form part of the actually living body, they are to some extent stable, but when removed from this they require nothing more than the presence of oxygen, the existence of moisture, and a moderate degree of warmth,

to insure their decomposition. These conditions, though essential, are so universally present, that animal and vegetable matters are generally considered as liable to decay "of themselves." If, however, such substances be deprived of access of air, or be frozen, or have their water driven off by desiccation, they are capable of retaining their chemical composition for an apparently indefinite period of time; and one or other of these conditions is carried out in all processes which have as their end the preservation unchanged of the organic substances which form the bodies of animals and plants.

3. Differences between Dead and Living Bodies.

Whilst all living bodies, whether animal or vegetable, are composed essentially of organic substances, there are nevertheless associated with the living organism larger or smaller amounts of matter which is practically dead. On the other hand there are numerous secondary organic products which at no time enter into the composition of living bodies, and which are therefore just as much "dead" substances as the genuine inorganic substances.

The general distinctions between dead and living matter are the following:—

a. Mode of Increase.—Living bodies possess the power of taking into their interior certain materials (food), foreign to those composing their own substance, and of converting these into the materials of which they are themselves built up. This process is known as "assimilation," and it is in virtue of this that living bodies *grow*. The growth of the organism, therefore, and its increase in size, is not effected by the mere addition of matter from the outside, but by the taking of matter into the interior of the body, and its modification there.

On the other hand, when dead bodies increase in size (as crystals do in supersaturated solutions), this is effected simply by the addition of particles from the outside, or, as it is technically called, by the "accretion," instead of by the "intussusception," of matter. The newly added particles undergo no change from their previous constitution, and the essential element of "assimilation" is thus wanting, so that the process is in no sense one of "growth" properly so called.

b. Cyclical Change.—All dead matter tends to assume a condition of permanent stability and repose. Living matter, on the other hand, is pre-eminently distinguished by its ten-

dency to pass through a series of cyclical changes, all the actions of living bodies being accompanied by a corresponding destruction of the matter by which these actions are effected. All these cyclical changes are effected by the slow but incessant reduction of the living matter of the organism to the non-living condition. Active life, therefore, can only be carried on by the constant destruction of portions of the living matter of the body; and to meet the loss thus caused, it is necessary that a corresponding amount of non-living matter should be constantly "assimilated," and raised from the statical condition of dead matter to the dynamical condition of living matter. The matter composing the organism is thus in a state of constant flux, and the processes by which the living matter of the body is incessantly undergoing destruction and repair are grouped together under the head of "metabolic" processes.

c. Relations to the outside World.—Dead bodies are subject to the physical and chemical forces of the universe, and have no power of suspending these forces, or modifying their action, even for a limited period. On the other hand, living bodies, whilst subject to the same forces, are the seat of something in virtue of which they can override, suspend, or modify the actions of the physical and chemical forces by which dead bodies are exclusively governed. Dead matter is completely passive, unable to originate motion, and equally unable to arrest it when once originated. Living matter, so long as it *is* living, is the seat of *energy*, and can overcome the primary law of the *inertia* of matter. However humble it may be, and even if permanently rooted to one place, every living body possesses, in some part or other, or at some period of its existence, the power of independent and spontaneous movement—a power possessed by nothing that is dead. Similarly, the chemical forces, which work unresisted amongst the particles of dead matter, are in the living organism directed harmoniously to given ends, their action regulated under definite laws, and their natural working often strikingly modified, or even temporarily suspended, and this as effectually and as perfectly in the humblest as in the highest of created beings.

As a result of this, dead bodies exhibit nothing but *reactions*, and these purely of a physical and chemical nature, whilst they show no tendency to pass through periodical changes of state. On the other hand, living bodies exhibit distinct *actions*, and are pre-eminently characterised by their tendency to pass through a series of cyclical changes, which follow one another in a regular and determinate sequence.

d. Reproduction.—Every living body has the power of reproducing its like. Directly or indirectly, every living body has the power of giving off minute portions of its own substance, which, under proper conditions, will be developed into the likeness of the parent.

4. Nature, Conditions, and Origin of Life.

Life has been variously defined by different writers. Bichat defines it as "the sum total of the functions which resist death;" Treviranus, as "the constant uniformity of phenomena with diversity of external influences;" Dugès, as "the special activity of organised bodies;" and Béclard, as "organisation in action." All these definitions, however, are more or less objectionable, since they either really mean nothing, or the assumption underlies them that life is inseparably connected with organisation. In point of fact, no rigid definition of life appears to be at present possible, and it is best to regard it as being simply a tendency exhibited by certain forms of matter, under certain conditions, to pass through a series of changes in a more or less definite and determinate sequence. The essential phenomenon of vitality is, therefore, in the words of Herbert Spencer, "the continuous adjustment of internal relations to external relations," and life, in its *effect*, is the totality of the functions of a living being. Life, however, may also be considered as a *cause*, since amongst the phenomena presented by all living beings there are some which cannot be referred to the action of known physical or chemical laws, and which, therefore, temporarily at any rate, we must term "vital," without in any way thereby implying that they are not dependent upon material causes.

Whilst the nature of life thus does not admit of rigid definition, we find that the phenomena of vitality can only be manifested under certain *conditions*, some of these being *intrinsic* and indispensable, whilst others are *extrinsic*, and not in themselves, or collectively, essential.

The only intrinsic condition of life appears to be the existence of a special "*physical basis*," as it has been termed. We do not find, namely, that the phenomena of vitality can be manifested by any and every form of matter. On the contrary, and as might have been expected upon *a priori* grounds, all living bodies appear to be composed of a special substance, which is the material basis of life, and which seems to be substantially identical in all alike. No living body is throughout

composed of this living basis, but all contain a greater or smaller amount of other materials, which are in one sense dead. The real phenomena of vitality are conditioned, therefore, by certain special portions of the organism, which are alone formed of this living matter; and this matter in chemical composition and physical characters appears to be identical in all living beings whether animal or vegetable.[1] To this physical basis the names of "protoplasm" or "bioplasm" are applied. The lowest organisms consist of little else but simple unmodified protoplasm; but even in the most complex organisms it can be shown that their essential parts, in which alone vitality is inherent, are similarly composed of protoplasmic matter.

As regards its chemical nature, protoplasm belongs to the great group of substances which are known as "albuminoids" or "proteids," and of which albumen or white-of-egg is a typical example. It is composed of the four elements, carbon, hydrogen, oxygen, and nitrogen, united into a proximate compound, and it is seen in a moderately pure form in the yelk of eggs, in the contents of growing cells, in white blood-corpuscles, and in many of the lower forms of life. Examined microscopically, protoplasm presents itself as a clear, viscid, or semi-fluid substance, commonly containing minute granules, and usually small clear spaces ("vacuoles"), but not exhibiting a composition out of definite parts or "organs." It always contains more or less water, and its precise consistence depends upon the amount of this which may be present.

Protoplasm, further, belongs to the group of substances which are known as "colloids," being incapable of crystallisation, and having little or no power of diffusing itself through the pores of an animal membrane. Hence, protoplasm can be stored within the organism, and retained without loss within the delicate walls of cells. Protoplasm always contains, however, a larger or smaller quantity of certain mineral substances, which belong to the group of the so-called "crystalloids," being capable of crystallisation, and having the power of ready transmission through animal membranes.

Lastly, protoplasm is solidified or "coagulated" by exposure

[1] It has not yet been shown that the living matter which we designate by the convenient term of "protoplasm" has universally and in all cases a constant and undeviating chemical composition; and there is, indeed, reason to believe that this is not the case. It is also certain that there are other materials, the exact use of which we do not at present know, which are absolutely essential to the maintenance of life, probably even in its humblest manifestations.

to a temperature of from 110° to 120° F., and is stained of a red colour by immersion in an ammoniacal solution of carmine.

In its living condition, protoplasm exhibits the phenomena which are characteristic of living beings in general. Thus living protoplasm, in its simplest and most elementary forms, has the power of assimilating foreign materials, and hence is able to nourish itself and to grow. Similarly, living protoplasm has the power of detaching portions of its own substance, which may become developed into new and independent beings. Again, living protoplasm has the power of movement. This power is reduced to its minimum when the protoplasm is confined within a rigid outer wall or envelope; but even in such cases—as in vegetable cells—we may often observe a circulation or "rotation" of the enclosed granules, when the protoplasm is diluted with water. If the protoplasm is not confined within a rigid envelope, it possesses the power of throwing out longer or shorter prolongations or processes of its own substance ("pseudopodia"), by means of which it can obtain food, or, if free, move about (fig. 1). Nor is this power of emitting "pseudopodia" restricted to animal protoplasm, since it is seen in various of the lower plants; and Dr Francis Darwin has shown that the cells of the glandular hairs of the Common Teasel (*Dipsacus sylvestris*) emit mobile filaments of protoplasm quite similar to the "pseudopodia" of many of the lower animals. Lastly, we may infer that living protoplasm, in all its forms, is endowed with some power of sensation, though it is not possible to prove this positively.

While protoplasm is the only essential or intrinsic condition of life, the phenomena of active vitality can nevertheless not be manifested except under certain non-essential or extrinsic conditions. In the absence of these extrinsic conditions, the organism may remain for a longer or a shorter period in a state of "dormant" or "potential" vitality, as is seen in the eggs of many animals and the seeds of many plants, or as may occur in some cases even in adult animals or plants. The principal extrinsic conditions of life are the following:—

1. *The presence of water*, living protoplasm invariably containing a larger or smaller amount of water. Complete expulsion of water from the organism is probably invariably fatal; but ordinary desiccation, though it abolishes all the manifestations of active vitality, is nevertheless not necessarily destructive to life. Thus many minute organisms (such as Rotifers, Nematoids, and Infusorians) may pass under desiccation into a condition of suspended or dormant vitality, becoming again active when water is supplied to them.

2. *A certain temperature*, varying from near the freezing-point to 120° or 130° F. As regards the higher animals, the vital resistance to changes of temperature is slight, and any

Fig 1.—*Protogenes porrecta*, one of the *Monera* (after Max Schultze), greatly enlarged. The organism consists of a naked mass of granular protoplasm, which has the power of emitting long thread-like pseudopodia.

great alteration of the normal temperature of the body, either in the way of elevation or reduction, is generally fatal. Such changes, however, if not excessive, and if slowly produced, may only give rise to a condition of dormant vitality. Thus, many of the higher animals under a prolonged reduction of temperature pass into a condition of "winter-torpidity" ("hibernation"). In this state the animal functions of locomotion and sensation are wholly abolished, and the purely vegetative functions of nutrition (such as respiration, the circulation of the blood, and the like) are reduced to their minimum. Among the higher animals, this condition is only possible in such forms as can previously accumulate a large store of fat and albumen (as, for example, in the Hedgehog and the Brown Bear). Conversely, a long-continued maintenance of the tem-

perature of the body at a level higher than is compatible with active life, may give rise to a condition of "summer-torpidity" ("æstivation"). In this case the suspension of active vitality is apparently due to the abstraction from the tissues of a certain amount of water. A temporary torpidity of this kind may be produced in any climate in small organisms (Rotifers, Infusoria, &c.); or it occurs in hot climates as a periodic phenomenon even among the higher animals (*Crocodilia*, *Lepidosiren*, &c.).

As regards the lower organisms, the vital resistance to changes of temperature is often very great. Many of the lower forms of life can be frozen without thereby suffering more than a temporary suspension of vitality; while certain microscopic types (bacteria and vibrios) have been shown in some cases to successfully withstand exposure to a temperature considerably higher than the boiling-point of water.

3. *The presence of free oxygen.*—As active life is dependent upon the oxidation of the living matter of the body, the presence of free oxygen may be considered as normally essential. There are, however, certain of the lower types of life (bacteria and vibrios) which appear under certain circumstances to be capable of exhibiting active vitality, even when deprived of oxygen.

4. There are, finally, certain extrinsic conditions, such as the presence of sun-light, which are essential for the maintenance of life *as a whole*, though by no means necessarily demanded for the life of individuals. Thus, vegetable life is as a whole dependent upon sun-light; and though animals can subsist in darkness, animal life is in reality dependent upon plant-life, so that the total absence of the sun would extinguish all life whatever.

With regard to the question of the *origin* of living matter, or, in other words, of the origin of life, it is to be noted in the first place that the question is one involving two separate problems, which are essentially distinct, and which under no circumstances could be solved by similar means. One of these problems relates to the origin of life upon the earth in the beginning, and deals with the question as to how the primordial living beings were produced. The solution of this problem is, so far as science is concerned, altogether impracticable, since Geology has rendered it abundantly plain that we need never hope to find any scientific evidence, direct or indirect, which would justify us in forming anything beyond a more or less probable hypothesis on the subject.

On the other hand, we have the question as to how living

beings are produced *now*, and this is a problem wholly within the sphere of legitimate scientific investigation. Up to about the middle of the seventeenth century scientific observers generally believed that living beings might be produced *de novo* from dead matter, under suitable conditions, without the pre-existence of similar living beings. This supposed production of living beings directly from dead matter constitutes what has been called "spontaneous generation," *generatio equivoca*, or "abiogenesis." With regard to the higher animals and plants, there is, of course, the absolute certainty that new individuals can only be produced by reproduction, and therefore through the medium of pre-existing individuals of the same kind. The question of abiogenesis is thus narrowed at the present day to the alleged equivocal generation of certain low forms of animal and vegetable life, all of which are microscopic, and most of which can only be examined under high powers of the microscope. The *theory* of abiogenesis is that under certain circumstances dead matter may build itself up into living matter, without the intervention of already existing protoplasm; and that this process has not only occurred once, but has always been, and still is, regularly and constantly going on. Without entering here into the complicated, and in many respects contradictory, experimental evidence upon this subject, it may be stated that there is not in the meanwhile any sufficient scientific basis for the belief that even the simplest forms of animal or vegetable life are at the present day produced by any process of abiogenetic generation. On the contrary, there is every reason to believe that, whatever may have been the case with the first beginnings of life, living protoplasm is now invariably derived from pre-existent living protoplasm.

5. Elementary Forms of Living Matter.

A single microscopic mass of protoplasm may be capable of performing all the great vital functions, and may thus constitute an entire and independent organism. Even the highest and most complex organisms begin their life as a single minute mass of protoplasm, and in their most fully developed condition are essentially aggregates of such masses.

As has already been seen, simple structureless protoplasm is in itself all that is necessary for the manifestation of vital phenomena, but such protoplasm usually presents itself under some definite form. The most general, and at the same time the most fundamental, form under which protoplasm presents

itself, is that of what is termed a "cell," and we may therefore regard this as the vital unit. A "cell," in the strict acceptation of the term, consists of a mass of protoplasm (the "cell-contents"), surrounded by a more or less rigid envelope (the "cell-wall"), and having in its interior a central vesicular or solid body ("the nucleus"), within which there is usually a still smaller body (the "nucleolus"). Such a cell (fig. 2, A) may be microscopic in size, or may attain considerable dimensions (as in the ovular cell of many animals).

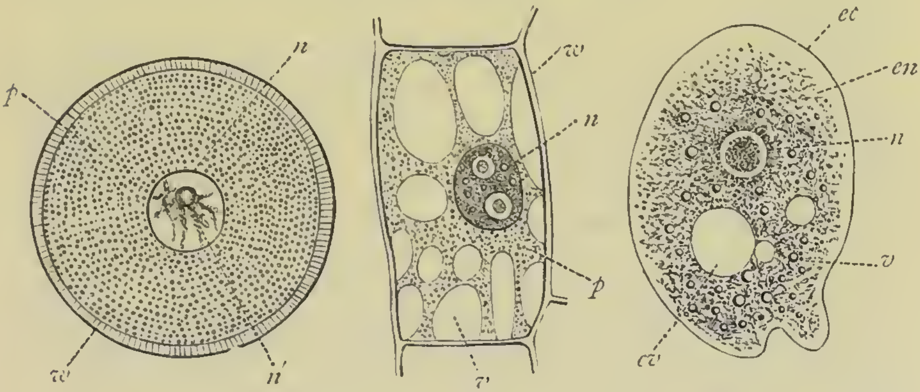


Fig. 2.—A, Isolated cell (ovum of a Sea-Urchin), greatly enlarged. *w* Cell-wall (vitelline membrane"); *p* Protoplasmic cell-contents ("yelk"); *n* Nucleus ("germinal vesicle"); *n'* Nucleolus ("germinal spot"). B, A vegetable cell, greatly enlarged. *w* Cell-wall; *p* Protoplasmic cell-contents, showing large spaces or "vacuoles" (*v*), filled with sap; *n* Nucleus, with two nucleoli. C, Gymnocyte or naked cell (young *Amœba*), greatly enlarged. *ec* External layer of clear protoplasm ("ectoplasm"); *en* Internal mass of fluid, granular protoplasm ("endoplasm"); *n* Nucleus; *v* One of the "vacuoles" in the endoplasm; *cv* Large, permanent, contractile vacuole ("contractile vesicle"). (After Fol, Sachs, and Leidy.)

The "cell-wall," or outer envelope of the cell, may be regarded as formed by chemical change of the external layer of the cell-contents. It is thin in young cells, but is liable to become thicker with age, the nutrition of the cell being thereby interfered with, since the thickness of the wall prevents the free interchange of matter between the internal protoplasm and the external medium. The cell-wall may be imperforate, but it is often tubulated or porous, thus allowing the contained protoplasm to give out external processes (as in the ovular cell of many animals), or permitting a direct connection between the protoplasm of adjoining cells (as in many plants). As a rule, the cell-wall is composed of some albuminoid substance, in the case of animal cells; but is formed of cellulose or woody matter in vegetable cells.

The "cell-contents" are primitively composed of protoplasm

(fig. 2, A, *p*), through which are scattered numerous granules (probably of a fatty nature), along, in many cases, with minute clear globular spaces, which are occupied by fluid, and which are termed "vacuoles" (fig. 2, B, *v*). As the cell becomes older, the protoplasm gradually becomes reduced in amount, and it may finally become wholly replaced by some other substance (such as fat). As the cell-wall is more or less rigid, the contained protoplasm cannot throw out processes or "pseudo podia," except in cases where the cell-wall may be porous. An internal circulation, or "rotation," of the protoplasm, is, however, often observable.

The "nucleus," or "endoplast," of the cell is a hollow or solid body, of variable form, contained within the protoplasmic cell-contents (fig. 2, *n*). It is usually deeply stained by carmine, and it may be regarded as a kind of centre for the vital activity of the cell. Very often the nucleus becomes smaller, or disappears altogether, as the cell grows older. In other cases, more than a single nucleus may be present. The "nucleolus" is a still smaller body, contained within the nucleus, and sometimes in turn containing a central spot of still more minute dimensions. The nucleolus sometimes gives off radiating threads or processes of protoplasm (fig. 2, A, *n'*).

A typical "cell" is constituted as above described, and we may regard this as pre-eminently the elementary form of living matter. It is not unusual, however, to find that certain of the structures which are present in a typical "cell" may be wanting in an elementary mass of protoplasm. Thus the external envelope or "cell-wall" is commonly wanting, the vital unit then consisting of a mass of granular and vacuolated protoplasm, with a nucleus and nucleolus, but without a definite investment. Such a structure has been termed a "gymnocyte" (fig. 2, C). In such cases, though no definite "wall" is present, it is usual to find that the outer layer of the protoplasm ("ectoplasm") is comparatively firm, and at the same time clear and free from granules; while the internal protoplasm ("endoplasm") is comparatively fluid, and is filled with granules and vacuoles. Owing to the absence of a restraining wall, the protoplasm of a "gymnocyte" has the power of throwing out variable and temporary processes of its own substance ("pseudopodia"), by means of which it obtains food and moves about.

In other cases, again, not only is the cell-wall absent, but the nucleus and nucleolus are likewise not developed. In such a case we have to deal simply with an independent mass of granular protoplasm without a central nucleus, or a

containing-wall, and to such Haeckel has given the name of a "cytode" (fig. 3). In some cases, both among animals and plants, a number of cytodes may join together to form a sort of reticulation, to which the name of "plasmodium" is applied.

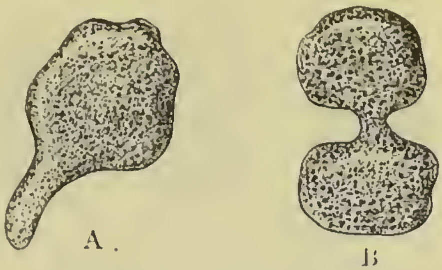


Fig. 3.—*Protamœba primitiva*, a "cytode," or non-nucleated mass of protoplasm, greatly enlarged (after Haeckel). A, An individual with a single pseudopodium protruded; B, Another individual, dividing by transverse cleavage into two portions.

While we may consider the "cell" as the normal vital unit, it will be evident from the above that the simplest expression of life is truly to be found in the living protoplasm, and that the cell-wall, nucleus, and nucleolus are subsidiary to this, and comparatively non-essential.

A single microscopic mass of protoplasm—whether in the form of a cell, a gymnocyte, or a cytode—may constitute an entire organism. Such a mass of protoplasm has therefore the power not only of nourishing itself, but also of giving rise by reproduction to new masses of protoplasm similar to itself. The principal methods by which a primitive mass of protoplasm reproduces itself are twofold. In the first of these methods (fig. 4), the original mass of protoplasm throws out a bud or process of its own substance at some point in its periphery. This bud gradually increases in size, while its connection with the parent mass becomes more and more constricted. Ultimately, the bud is thrown off as a new and independent mass of protoplasm, and it may develop a new nucleus, nucleolus, and cell-wall. The above mode of increase is not unusual both among animal and vegetable cells, and it constitutes what is known as "gemmation." A still more common mode, in which a primitive mass of protoplasm multiplies itself, is by a simple division of its substance into two or more parts, constituting what is known as "cleavage" or "fission." In this process (fig. 5), the protoplasm

Fig. 4.—Cells of the Yeast-plant, producing fresh cells by a process of gemmation. Magnified 2800 diameters. (After Beale.)

divides itself into two nearly equal halves, the cleavage being generally preceded by a partition of the nucleus into two nuclei. The process is, however, really independent of the nucleus, as it commonly takes places in a mass of protoplasm ("cytode") in which a nucleus is not developed (fig. 3). A third, less common, method of reproduction is what is termed the "endogenous" production of new cells. This is constituted by the appearance in the protoplasm of the primitive cell of a larger or smaller number of secondary nuclei, round which the protoplasm gradually segregates itself to form so many daughter cells.

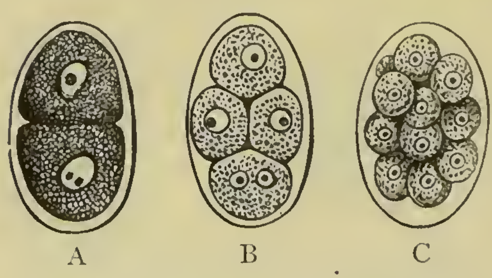


Fig. 5.—Cleavage of the yelk of the ovum of *Ascaris nigrovenosa*. (After Kölliker.)

As has been seen, a single cell, gymnocyte, or cytode may constitute an entire and independent organism. In such cases, the masses of protoplasm produced by one or other of the above-mentioned methods of multiplication are separated from the parent, to lead an independent life as new organisms. In the great majority of animals and plants, however, the new masses of protoplasm, produced as above, are not separated from the parent mass, but remain connected with it and with one another. Hence the higher animals and plants are "multicellular," the primitive ovular cell being ultimately converted into an aggregate of cells, constituting the adult organism. The life of such an aggregate is the combined life of its constituent units; but each cell of the aggregate has a life of its own, which is shorter than that of the whole organism, and is independent of it. Moreover, in these multicellular aggregates (fig. 6), the constituent cells usually come in the course of growth to lose their primitive similarity. They become variously modified, or "differenti-

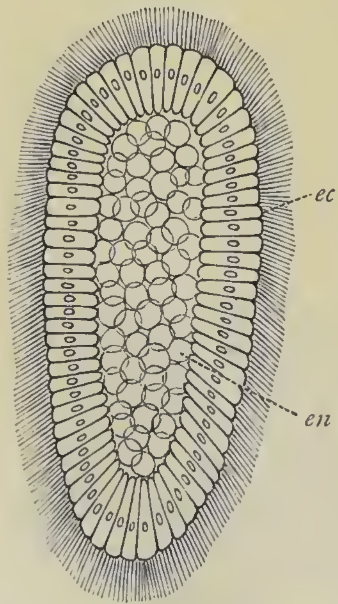


Fig. 6.—Embryo ("planula") of a Cœlenterate animal, greatly magnified. The organism is composed of many cells, produced by the division of the primitive ovular cell; and the cells which form the outer layer of the body (*ec*) are different to those forming the interior (*en*).

ated," in different regions of the body, thus constituting the so-called "*tissues*" of the body. The chief groups of tissues are the "connective tissues" (ordinary connective tissue, cartilage, bone, &c.), the "epithelial tissues" (epithelium, epidermis), the "muscular tissues" (voluntary and involuntary muscles), and the "nervous tissues" (nerve-cells and nerve-fibres). Each tissue discharges its own function in the economy; and they are usually so combined with one another as to give rise in the higher animals and plants to those definite parts or structures which are known as "organs." All living beings which possess such definite "organs" are said to be "organised." As has been already seen, however, "organisation" is not essential to life, all the fundamental phenomena of vitality being manifested by apparently structureless protoplasm.

6. Aspects in which a Living Being may be studied.

Every living being, whether animal or vegetable, may be studied from various points of view, its investigation from each of which constitutes a special branch of biological science. The aspects under which a living being requires to be studied, in order to obtain a complete history of it, are the following:—

1. *Morphology.*—The first and most important knowledge which it is necessary to obtain with regard to any animal relates to its external and internal *structure.* This constitutes what is known as "Morphology," and embraces not only a knowledge of its internal and external organisation (anatomy), but also an acquaintance with such superficial features as colour and the like, which are not strictly anatomical. The term "Histology" is further employed to designate that branch of Morphology which is specially occupied with the investigation of minute or microscopical tissues.

2. *Physiology.*—Having acquired a knowledge of the form and structure of a living being, we have next to study its vital functions, this constituting the science of "Physiology." Under this head we have to investigate all the functions exercised by living bodies, or by the various definite parts or organs of which most animals are composed. All these functions come under three heads:—1. *Functions of Nutrition*, divisible into functions of absorption and metamorphosis, comprising those functions which are necessary for the growth and maintenance of the organism. 2. *Functions of Reproduc-*

tion, whereby the perpetuation of the species is secured. 3. *Functions of Relation*, comprising all those functions (such as sensation and voluntary motion) by which the external world is brought into relation with the organism, and the organism in turn reacts upon the external world.

Of these three, the functions of nutrition and reproduction are often collectively called the functions of organic or vegetative life, as being common to animals and plants; while the functions of relation are called the animal functions, as being more especially characteristic of, though not peculiar to, animals.

3. *Development.*—While Morphology deals with the form and structure of the adult being, the science of "Development" or "Embryology" is concerned with the study of the various changes through which the organism passes before it assumes its mature and final characters. As regards the higher animals, these changes are mostly numerous and complex, and the study of development constitutes one of the most intricate of the departments of Biological Science.

4. *Geographical Distribution.*—Under this head is embraced a knowledge of the relations of each living being to the world outside it. In studying, therefore, the "Distribution in Space" of an animal, we have to investigate the area which it now inhabits, the conditions of its existence, and the like.

5. *Distribution in Time.*—Not only has each living being a "geographical distribution," but it also has a *history* as a species; though it is only in the case of organisms possessing hard parts or skeletons that we can, as a rule, investigate this history. In the case, therefore, of each animal, it is necessary to investigate, so far as possible, the time of its first introduction upon the earth, the duration of its existence as a species, its geographical range in past time, and other similar points. The study of these questions constitutes a special department of Biology, to which the name of "Palæontology" is usually applied.

6. *Classification or Taxonomy.*—Under this head are embraced all those points which are connected with the relations of each living being to other different forms of life, and which serve to fix the place occupied by any given type in the entire series.

7. *Evolution.* — Lastly, there exists a branch of Biology which does not deal with a living being as an *individual*, but which investigates the origin and history of those groups of similar individuals which constitute what are understood as *species*. This constitutes the science of "Evolution."

7. Differences between Animals and Plants.

Living beings, as has been seen, are usually divided into two great series, the one comprising animals, the other plants; and in accordance with this, the science of Biology is broken up into the two subordinate sciences of Zoology and Botany. When we come, however, to inquire into the differences which distinguish and separate animals from plants, we find that these are by no means so clearly marked as we might have expected. In individual cases it is often extremely difficult to come to any decision as to the reference of a given organism to the animal or the vegetable kingdom; and there are numerous instances in which the determination of this point is, with our present knowledge, largely arbitrary. So strongly, in fact, has this difficulty been felt, that some observers have established an intermediate kingdom (the *Regnum protisticum* of Haeckel), a sort of no-man's-land, for the reception of those debatable organisms which cannot be definitely and positively classed either among vegetables or among animals.

In the case of the higher animals and plants, the difficulty above alluded to is not felt; the former being at once distinguished by the possession of a nervous system, of motor power which can be voluntarily exercised, and of an internal cavity fitted for the reception and digestion of solid food. The higher plants, on the other hand, possess no nervous system or organs of sense, are incapable of independent locomotion, and are not provided with an internal digestive cavity, their food being wholly fluid or gaseous. These distinctions, however, do not hold good as regards the lower and less highly organised members of the two kingdoms, many animals having no nervous system or internal digestive cavity, whilst many plants possess the power of locomotion; so that we are compelled to institute a closer comparison in the case of these lower forms of life.

a. Form.—As regards external configuration, of all characters the most obvious, it must be admitted that no absolute distinction can be laid down between plants and animals. Many of our ordinary zoophytes, such as the Hydroid Polypes, the Sea-shrubs and Corals—as, indeed, the name zoophyte implies—are so similar in external appearance to plants that they were long described as such. Many of the *Polyzoa* are equally plant-like in appearance. Amongst the lower unicellular forms of life (*Protozoa* and *Protophyta*), the resemblance in external form is so close as to entirely preclude the

employment of this character in deciding on the animal or vegetable nature of the organism. Indeed, there are many of these lowly-organised beings, such as the *Volvoces* (fig. 7, *c*), as to which it is still quite uncertain whether they are properly referable to the animal or the vegetable kingdom. Moreover, the embryonic forms or "zoöspores" of certain undoubted plants (such as *Protococcus nivalis*, *Vaucheria*, &c.) are provided with ciliary appendages, with which they swim about (fig. 7, *a* and *b*), thus coming to closely resemble the undoubtedly animal Infusorians.

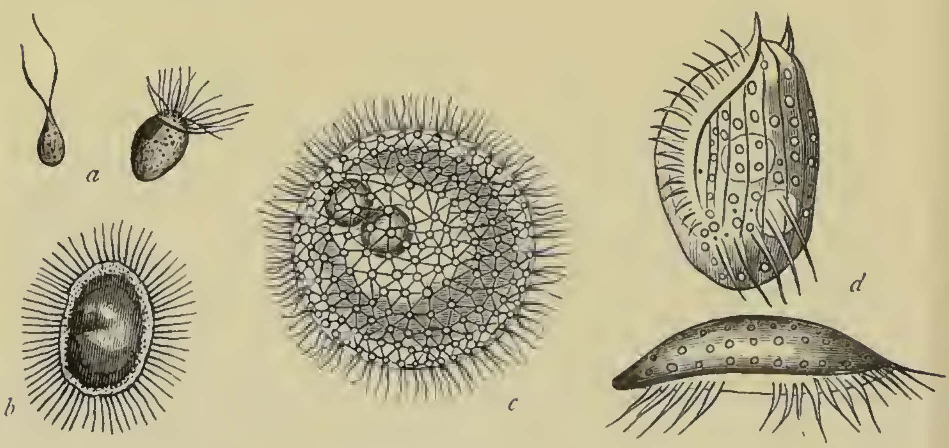


Fig. 7.—Algæ and Infusoria. *a* Ciliated zoöspores of *Confervæ; b* Ciliated zoöspore of *Vaucheria; c Volvox globator*, a locomotive fresh-water plant (?); *d Euplotes charon*, one of the *Infusoria*. All greatly magnified.

b. Internal Structure.—Here, again, no line of demarcation can be drawn between the animal and vegetable kingdoms. In this respect all plants and animals are fundamentally similar, the essential structural unit being in both the "cell."

c. Chemical Composition.—Plants, speaking generally, exhibit a preponderance of ternary compounds of carbon, hydrogen, and oxygen — such as starch, cellulose, and sugar — whilst nitrogenised compounds enter more largely into the composition of animals. Still both kingdoms contain identical or representative compounds, though there may be a difference in the proportion of these to one another. Moreover, the most characteristic of all vegetable compounds—viz., cellulose—has been detected in the outer covering of the Sea-squirts, or Ascidians (*Tunicata*); and the so-called "glycogen," which is secreted by the liver of the Mammalia, is closely allied to, if not absolutely identical with, dextrine, a substance isomeric with starch. As a general rule, however, it may be stated

that the presence in any organism of an external envelope of cellulose raises a strong presumption of its vegetable nature. In the face, however, of the facts above stated, the presence of cellulose cannot be looked upon as absolutely conclusive. Another highly characteristic vegetable compound is *chlorophyll*, the green colouring-matter of plants. Any organism which exhibits chlorophyll in any quantity, as a proper element of its tissues, is most probably vegetable. As in the case of cellulose, however, the presence of chlorophyll cannot be looked upon as a certain test, since it occurs normally in certain undoubted animals (*e.g.*, *Hydra viridis*, the common Fresh-water Polype; the Trumpet Animalcule or *Stentor;* certain Planarians, &c.).

d. Motor Power.—This, though broadly distinctive of animals, can by no means be said to be characteristic of them. Thus, many animals in their mature condition are permanently fixed, or attached to some foreign object; and the embryos of many plants, together with some adult forms, are endowed with locomotive power by means of those vibratile, hair-like processes which are called "cilia" or "flagella," and which are so characteristic of many of the lower forms of animal life. Moreover, many of the higher plants exhibit movements which are essentially similar to those presented by animals, and which are quite as extensive as is compatible with their fixed and rooted condition; while contractility is an inherent property of vegetable protoplasm, just as much as it is of that of animals.

e. Metabolic Processes.—A much more valid distinction between animals and plants than is yielded by any of the points previously considered, is afforded by the nature of the nutritive or metabolic processes in each. Plants, as a whole, differ from animals in possessing the power of converting inorganic into organic matter. The *food* of plants consists of carbonic acid, ammonia, water, and certain mineral salts, these being materials which occur in nature independently of life. Out of these stable inorganic materials the plant has the power of building up protoplasm and the other unstable organic compounds of which its tissues are composed. More especially, plants possess the power, denied to all undoubted animals, of breaking up or decomposing carbonic acid gas, retaining the carbon of the same and setting free the oxygen. For the exercise of this power, however, two conditions are requisite—viz., the presence of sun-light, and the existence in the plant-tissues of *chlorophyll.*

As has been previously seen, chlorophyll is the green

colouring-matter of plants, but occurs also in various animals. It usually presents itself in the form of minute granules ("chlorophyll-corpuscles"), in the interior of which starch-grains are formed under the action of sun-light. As the power of decomposing carbonic acid belongs to the chlorophyll-corpuscles, it follows that it is only by the green parts of plants that this feat of vital chemistry is accomplished. The colourless parts of plants take no part in this action; and those plants which contain no chlorophyll (*i.e.*, Fungi) are unable to decompose carbonic acid. Hence, such plants obtain the organic compounds which they require directly from the tissues of other living beings (vegetables or animals), or from the decomposing remains of organisms. What is the precise function of chlorophyll in those animals which possess this colouring-matter has not yet been determined.

On the other hand, no known animal possesses the power of converting inorganic compounds into organic matter, but all, mediately or immediately, are dependent in this respect upon plants. All animals, as far as is certainly known, require ready-made proteinaceous matter for the maintenance of existence, and this they can only obtain in the first instance from plants. Animals, in fact, differ from plants in requiring as food complex organic bodies, which they ultimately reduce to very much simpler inorganic bodies. The nutrition of animals is a process of oxidation or burning, and consists essentially in the conversion of the energy of the food into vital work; this conversion being effected by the passage of the food into living tissue. Plants, therefore, are the great manufacturers in nature,—animals are the great consumers. The Fungi are, however, economically speaking, animals. There are also various "carnivorous" plants (the Sun-dew, Venus's Fly-trap, *Utricularia*, &c.) which are genuine plants in so far that they can decompose carbonic acid and build up starch, but which nevertheless have the power of digesting and absorbing ready-made organic materials in precisely the same way as animals do.

f. Reactions on the Atmosphere.—It may be roughly stated that the process of "respiration" is carried out, in one form or another, by all living beings alike, however simple their structure may be. The essential phenomenon in respiration, in all its forms, is the absorption of oxygen by the tissues, the union of the same with the waste carbon of the body, and the evolution of the carbonic acid thereby produced. The process is therefore one of the oxidation and combustion of the waste products of the organism; and it constitutes just as essential a portion of the vital processes of plants as it does

of those of animals. There is, however, an important distinction between animals and plants as regards their reaction upon the atmosphere. In both cases, the result of respiration is to add carbonic acid to the atmosphere; and in the case of animals this gas is always being exhaled into the air or water, since its evolution by the respiratory process is not interfered with, or neutralised in any way. In the case of plants, on the other hand, not only is the respiratory process less energetic, and the resulting carbonic acid correspondingly smaller in amount than in animals, but the carbonic acid is employed by the plant as *food.* By the action of the chlorophyll during the daytime, the carbonic acid of respiration is thus broken up into its constituent carbon and oxygen, the former being retained by the plant, while the latter is set free. Hence, during the daytime, the green parts of plants are constantly exhaling oxygen gas into the atmosphere, the evolution of carbonic acid being masked or neutralised by the process of digestion. There is thus maintained an approximate uniformity in the amount of carbonic acid present in the atmosphere. Animals, by their respiration, and by the decomposition of their bodies after death, are constantly adding carbonic acid to the atmosphere, and at the same time are incessantly abstracting oxygen. Plants, on the other hand, are constantly removing carbonic acid from the atmosphere, and are adding oxygen to it. Hence a balance is kept up, the members of each great division of living beings adding to the atmosphere the ingredients necessary to the life of the other.

8. Likenesses and Unlikenesses in Animals.

It is a matter of universal recognition that there exist points of similarity and dissimilarity between different kinds of animals. Many of the likenesses between animals are too obvious to escape the commonest observation. Thus, it is universally recognised that cats are like tigers, and that both in a less degree are like dogs and wolves. In the same way there is a general recognition that there is a common likeness between whales and fishes and seals, as there is also between bats and birds. On the other hand, many of the likenesses and unlikenesses between animals are more deeply hidden, and can only be determined by close and methodical investigation. Moreover, it is easy to discover that there are not only different *grades*, but also different *kinds* of likeness and unlikeness between different animals. Zoology, as a science,

is largely based upon the study of the points of similarity and dissimilarity among animals, and the investigation of the causes to which these are due; and it becomes necessary, therefore, to consider the whole of this subject in some detail.

It has been already seen that there are two principal aspects in which each animal may be studied. One of these is *morphological*, and deals with the form and structure of the animal; the other is *physiological*, and is concerned with the manner in which the organism discharges its vital functions. It is only in one or other of these two aspects that an animal can either resemble or differ from any other. Any two animals, therefore, may be like one another morphologically, but may be unlike physiologically; or they may be like physiologically and unlike morphologically; or, finally, they may not only agree in structure, but they may also have the same habits of life, and may discharge their physiological functions in the same way.

The primary morphological distinction among animals arises from the unicellular or multicellular character of the organism. The simplest organisms retain permanently the form of a simple or modified "cell"; or they may even not reach this, and may remain in the condition of a "cytode," or non-nucleated mass of protoplasm, by which all the vital functions are discharged. Such simple organisms are grouped together under the collective name of the *Protozoa*. The higher animals are all multicellular, the body consisting of an aggregate of cells; and these are grouped together under the collective name of the *Metazoa*.

a. Specialisation of Functions.—Among the simpler *Protozoa* the general protoplasm of the body discharges indifferently the functions of nutrition, reproduction, and relation, no particular portion being set apart for the discharge of any particular function. Hence these types exhibit nothing which can be properly spoken of as "organisation," nor do they show anything of that phenomenon which is known as "specialisation of functions." Among the higher *Protozoa* there is a commencement to a differentiation of the protoplasm into organs, and there is therefore to some extent a physiological distinction between different parts of the organism.

On the other hand, among the *Metazoa*, where the organism is an *aggregate of cells*, there is always to a greater or less extent what has been happily called a "physiological division of labour"; some of the cells being concerned with the nutrition of the organism, others with its reproductive functions, and others with its relations to the world outside it.

Hence in all the *Metazoa* there occurs, in varying degrees, a

specialisation of functions, or, in other words, a setting apart of special cells for the discharge of special functions. As the result of this physiological division of labour among the constituent cells of the organism, there occurs — in a similarly varying degree — a metamorphosis of the cells into different tissues.

Hence, *pari passu* with, and in consequence of, the physiological division of labour in the cells of the organism, there is produced an ever-increasing complexity of organic form and structure. Moreover, as we pass upwards from the lower to the higher *Metazoa*, we find that the primary physiological functions become themselves specialised, becoming broken up into numerous secondary functions, each of which requires specially modified cells for its discharge. It follows from the above that many of the morphological characters of animals are the result of the varying degrees to which their functions are specialised. It follows, further, that two animals which happen to lead the same kind of life, and which are therefore physiologically similar, must necessarily exhibit a certain degree of morphological likeness; while, conversely, two animals which have a real similarity in structure may appear to differ widely, if they are differently specialised from a physiological point of view.

As has been already mentioned, the three primary physiological functions of nutrition, reproduction, and relation, which may be said to be common to all organisms, are in the higher forms of life much more complex than in the lower. There is, therefore, a corresponding increase in the complexity of the organs which discharge these functions, as we ascend in the animal scale. Among the lower *Metazoa* particular groups of cells may discharge special functions, but may at the same time undergo little or no modification in structure. Cells of this kind, which are physiologically specialised, while remaining morphologically unmodified, constitute what have been called "elementary organs." Thus, the primitive organ of vision is only a group of epithelial cells capable of being excited by the stimulus of light.

A proper "organ," however, in any higher sense, is made up of specialised or *adapted* cells, usually along with secondary or subordinate tissues, so arranged as to form a more or less complex apparatus suited for the discharge of a particular function. Usually, also, a larger or smaller number of organs will be found to be associated together to form an "organ-system," devoted to the whole of some great series of functions, each individual organ doing some subordinate piece of work in the general series. Certain of these organ-systems—

namely, those devoted to nutrition and reproduction—are present in both the higher animals and the higher plants, and are spoken of as the systems of "organic" or "vegetative" life. The organ-systems connected with the higher or "animal" life are those of locomotion (the skeletal and muscular organs), and of sensation (the nervous system and organs of sense).

b. Use and Disuse of Organs.—Progressive and continuous use of an organ leads constantly to an increased ability on the part of the organ to discharge its functions, and commonly also to an increase in its actual size. A good example of this general law is to be found in the increased growth of a muscle consequent upon its frequent use.

On the other hand, disuse of an organ leads, in the first place, to a decreased ability on the part of the organ to discharge its special function. This is well seen in such cases as the functional inferiority of the muscles of the left arm to those of the right, in ordinary right-handed individuals. If the disuse be long-continued, partial atrophy of the organ commonly takes place, and the ability to perform the function may entirely disappear. If the disuse be at all complete, the organ may become a mere "rudiment," or "vestige"; as is seen, for example, in the case of the eyes of animals living habitually in caves.

c. Laws of Symmetry.—The higher *Metazoa* are composed of organ-systems, which are usually arranged according to some law of symmetry. In many forms the organ-systems are placed "radially" round a central point, from which they diverge in a star-like manner. This "radial symmetry" is seen most conspicuously in such types as the Star-fishes (fig. 8) and Sea-urchins, but occurs in many other organisms which were at one time grouped together under the name of "Radiate Animals."

In many other animals the organism consists of a succession of longitudinally placed segments, each of which is built upon the same plan as the others, and some or all of which may contain a repetition of certain organs. These segments (sometimes called "metameres") may be all closely similar to one another, or they may be specialised and differentiated in different regions of the body.

Lastly, when corresponding organs are placed on two sides of the middle line of the body (as commonly seen in the appendages of the body), the symmetry is said to be "bilateral."

d. Morphological Type.—As has been seen, the first point in which one animal may differ from another is the degree to which the principle of the physiological division of labour is

carried. The second point in which one animal may differ from another is in its "morphological type"; that is to say, in the fundamental plan upon which it is constructed. By

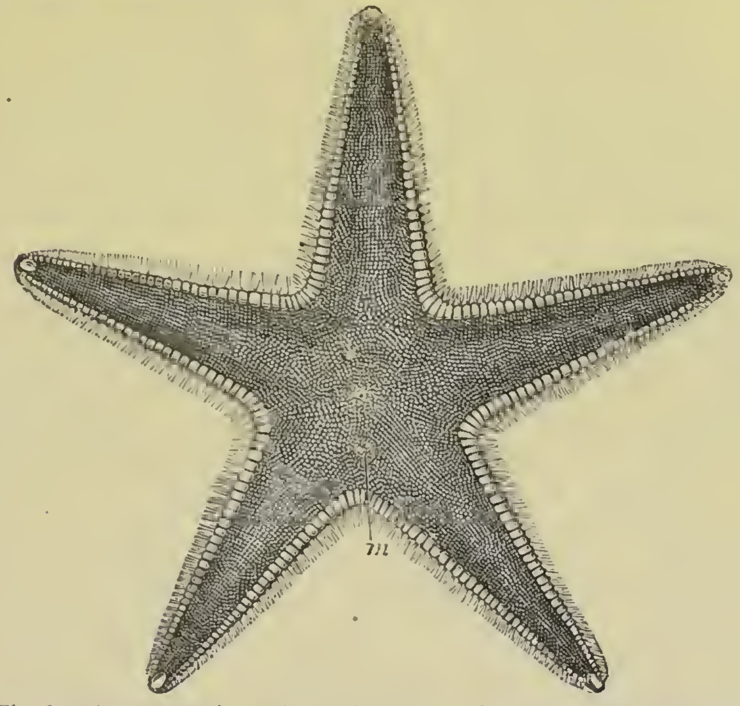


Fig. 8.—*Astropecten irregularis*, viewed from the upper side, showing the "radial symmetry" of the body.

one not specially acquainted with the subject, it might be readily imagined that each species or kind of animal was constructed upon a plan peculiar to itself and not shared by any other. This, however, is far from being the case; and it is now universally recognised that all the varied species of animals—however great the apparent amount of diversity amongst them—may be arranged under a very small number of primary morphological types or plans of structure. Upon one or other of these plans every known animal, whether living or extinct, is constructed. It follows from the limited number of primitive types or patterns, that great numbers of animals must agree with one another in their morphological type. It follows, also, that all so agreeing can differ from one another only in the sole remaining element of the question—namely, by the amount of specialisation of function which they exhibit. Every animal, therefore, as Professor Huxley has well expressed it, is the resultant of two tendencies, the one morphological, the other physiological.

The types or plans of structure, upon one or other of which

all known animals have been constructed, are technically called "sub-kingdoms"; and those generally recognised at the present day are known by the names Protozoa, Porifera, Cœlenterata, Echinodermata, Annulosa, Mollusca, and Vertebrata. We have, then, to remember that every member of each of these primary divisions of the animal kingdom agrees with every other member of the same division in being formed upon a certain definite plan or type of structure, and differs from every other simply in the grade of its organisation, or, in other words, in the degree to which it exhibits specialisation of function.

e. Homology of Organs.—"Homology" is defined as identity of *structure* in parts or organs, independently of *function*. It does not matter to what use two organs may be put by the animals possessing them, so long as it can be shown that they are built upon the same fundamental plan. In that case they are said to be "homologous" organs (fig. 9). For example,

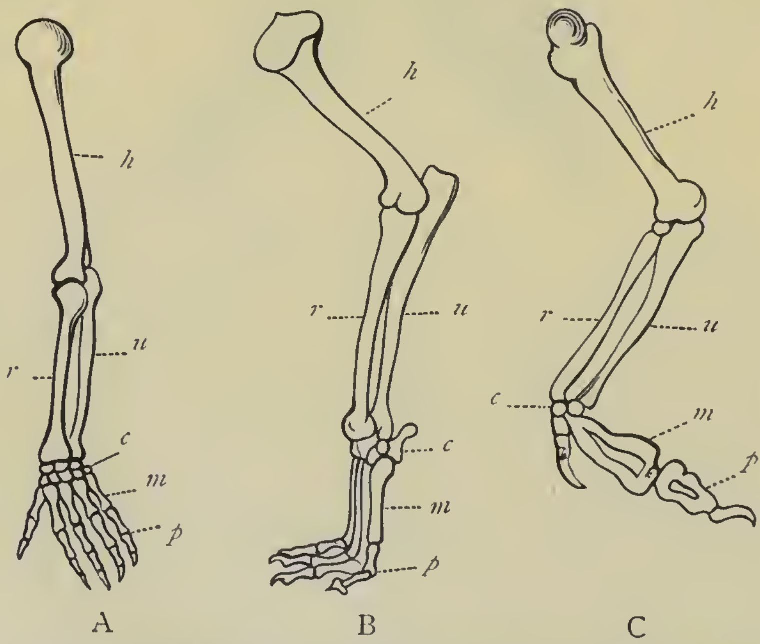


Fig. 9.—A, Arm of Man; B, Fore-leg of Dog; C, Wing of Bird. *h* Humerus; *r* Radius; *u* Ulna; *c* Carpus; *m* Metacarpus; *p* Phalanges.

the arm of a man, the fore-leg of a dog, the flipper of a whale, the wing of a bird, and the pectoral fin of a fish, are constructed upon the same morphological type, and are therefore *homologous* organs, altogether irrespective of the fact that their functions are for the most part different. Homology is therefore really a proof of the common origin of two organs, however

much they have been subsequently modified in accordance with physiological requirements. It follows that morphological or homological likenesses are the only ones of importance in determining the genealogy and systematic position of an animal.

The forms of "symmetry" already spoken of depend in reality upon the arrangement of homologous organ-systems. Thus, "radial symmetry" is dependent upon the fact that the body is composed of homologous parts radiately disposed. "Serial homology," again, is when the animal is composed of a succession of homologous parts arranged in a longitudinal series. This is exceedingly well seen in forms like the Lobster, the Centipede, and other Annulose animals, in which the body is composed of a series of homologous segments, carrying on both sides appendages which are likewise homologous, and which, therefore, exhibit "bilateral symmetry." The appendages, however, though actually constructed upon the same fundamental plan, may be much modified in different regions of the body, some being adapted for locomotion, some for prehension, some for mastication, and so on. While "lateral homology" indicates the morphological identity of the appendages on the two sides of the body, the term "vertical homology" is sometimes used to express the similar structural identity which may exist between the anterior and posterior appendages on the same side of the body. A good example of this is seen in the homology of the front and hind limbs of Vertebrate animals.

f. Analogy of Organs.—On the other hand, whenever we find in different animals organs fulfilling the same purpose and doing the same work, then we have to deal with a case of *analogy*—the organs are *analogous*, and the one is said to be the *analogue* of the other. In other words, those parts or organs are *analogous* which resemble one another physiologically and discharge the same *functions*, wholly irrespective of what their fundamental *structure* may be. In most cases the organs which would ordinarily be called "analogous" are such as differ from one another in structure, at the same time that they discharge the same duties. Thus the wings of a bird and the wings of an insect are analogous organs, since they are both organs of flight, and serve to sustain their possessor in the air. They are, however, in no way similar to one another, except when regarded from this physiological point of view; and they differ altogether from a morphological aspect, being in no way formed on the same fundamental plan. It often happens, however, that "analogous" organs have the deeper relation

to one another of being constructed upon the same morphological plan, in which case they are *both* analogous and homologous. Thus, the leg of man and the hind-leg of a dog are both analogous and homologous, since they are constructed upon the same plan and discharge similar functions.

g. Homomorphism.—Many examples occur, both among animals and among plants, in which families widely removed from one another as to their fundamental structure, nevertheless present a singular, and sometimes extremely close, resemblance in their external characters. Thus the composite Hydroid Zoophytes and the Polyzoa are singularly like one another—so much so, that they have often been classed together; whereas, in reality, they belong to different sub-kingdoms. Many other cases of this resemblance of different animals might be adduced, and in many cases these "representative forms" appear to be able to fill each other's places in the general economy of nature. This is so far true, at any rate, that "homomorphous" forms are generally found in different parts of the earth's surface. Thus, the place of the Cacti of South America is taken by the Euphorbiæ of Africa; or, to take a zoological illustration, many of the different orders of Mammalia are *represented* in the single order Marsupialia in Australia, in which country this order has almost alone to discharge the functions elsewhere performed by several orders. Speaking generally, the likeness between homomorphous types may be considered to be physiological or adaptive in its nature, and to be the result of a similar environment and habit of life.

h. Protective Resemblances.—A large number of animals exhibit peculiarities of colour or form, by which they are rendered difficult of detection when living in their natural haunts. Such peculiarities are spoken of as "protective resemblances," since they serve to protect the animal from its natural foes, or, in other cases, render it easier for the animal to steal unobserved upon its prey. Good examples of such protective resemblances are found in the white covering of many Arctic animals, or the tawny or sandy colours which are commonly prevalent among animals inhabiting deserts. In some cases, as among the insects known as Walking-leaves (*Phyllium*, fig. 10), these protective resemblances are carried to an extraordinary degree of perfection.

i. Mimicry.—The remarkable phenomenon known as "mimicry" consists in the close resemblance which certain animals assume to others, not necessarily nearly related to them, by which they derive some protection from their natural enemies. This resemblance is often so close that it looks as

if the one animal had copied the other, though, of course, there is no *conscious* action in the case. A good example of this is to be found in the close resemblance which the "clear-

Fig. 10.—Walking-Leaf Insect (*Phyllium*).

winged Moths" exhibit to Hornets and Wasps, and by which they are protected against the attacks of birds. Still more striking examples are found among Butterflies, where one species, which would itself be naturally liable to be eaten by birds, puts on the form and coloration of another species, which is protected against the attacks of birds by the possession of some disagreeable secretion. In other cases, the object of the mimicry is not strictly protective, but the mimetic species avails itself of its likeness to the species which it mimics, for the purpose of stealing into the nests of the latter, and of depositing its eggs therein.

j. Correlation of Organs.—What is understood by the term "correlation of growth," or "correlation of organs," is the occurrence of some organ or structure in association with some other organ or structure, with which it is not connected by any obvious or discoverable link. Thus, milk-glands are

"correlated" with the possession of two occipital condyles and of a simple mandible; a stomach adapted for rumination is correlated with the possession of only two functional toes to the foot, and the absence of the central upper incisors; an inflected angle of the lower jaw is correlated with the possession of "marsupial bones" or "marsupial cartilages"; a covering of feathers is correlated (in living forms) with saddle-shaped faces to the bodies of the cervical vertebræ. The above will serve to illustrate the general nature of the law of correlation of growth. Stated in its most general form, this law asserts that all the parts of the organism stand in some relation to each other, the form and characters of each being to some extent dependent on, and connected with, the form and characters of all the rest. By the help of this law it is often possible to infer from one organ the structure of the remainder of the organism. Thus, if we were acquainted with no other part of some animal than its skull alone, and if we found that that skull possessed two occipital condyles, and that each half of the lower jaw was composed of a single piece, we should be justified in concluding that the animal to which the skull belonged possessed mammary glands. We should also be justified in inferring many other facts about it, as, for example, that it possessed (or might have possessed) a hairy covering to the body, that its blood was hot, and that it possessed non-nucleated red blood-corpuscles. Similarly, if we met with a mammalian lower jaw, the angle of which was bent inwards, or "inflected," we should be warranted in concluding that the animal to which it belonged possessed "marsupial bones" or cartilages on the brim of the pelvis, and that the young were born in a very imperfect state of development.

The law of the correlation of organs, first fully established by Cuvier, is one of the greatest value in the investigation of extinct organisms, where it is never possible to examine more than a limited portion of the animal. It is to be remembered, however, that the law is a purely empirical one, and expresses nothing more than the result of experience; so that structures which we now know only as occurring in association may ultimately be found separate, and conjoined with structures of a different character. Moreover, it is to be borne in mind that in any two correlated structures it is not that *each* is correlated with the other, but that *one* of the two is correlated with the other. That is to say, of any two correlated organs, A and B, it may be true that A is never found without B, but it does not follow that B may not occur without A. Thus, the presence of a stomach adapted for "rumination" is invariably associated with an imperfect development of the incisors of the upper

jaw, the central upper incisors being always wanting; but it is not the case that an incomplete condition of the upper incisors, or the absence of the central ones, is necessarily correlated with the habit of chewing the cud. The proper way of putting the case is to assert that certain structures (A) are never found apart from other structures (B), though the latter may be present without the former. When, therefore, we find a lower jaw having its angle "inflected," we may, with our present knowledge, assert that the animal to which that jaw belonged must have possessed "marsupial bones" or "marsupial cartilages" upon the brim of the pelvis. If, however, we were to find a pelvis with marsupial bones, we should not be justified in asserting that the owner of the same must have possessed an inflected angle to the lower jaw. On the contrary, we know that such an assertion would be erroneous, since the "marsupial bones" are present in the Monotremes, in which the angle of the jaw has its usual form.

9. Classification.

Classification is the arrangement of a number of diverse objects into larger or smaller groups, according as they exhibit more or less likeness to one another. The excellence of any given classification will depend upon the nature of the points which are taken as determining the resemblance. Systems of classification, in which the groups are founded upon mere external and superficial points of similarity, though often useful in the earlier stages of science, are always found in the long-run to be inaccurate. It is needless, in fact, to point out that many living beings, the structure of which is fundamentally different, may nevertheless present such an amount of adaptive external resemblance to one another, that they would be grouped together in any "artificial" classification. Thus, to take a single example, the whale, by its external characters, would certainly be grouped amongst the fishes, though widely removed from them in all the essential points of its structure. "Natural" systems of classification, on the other hand, endeavour to arrange animals into divisions founded upon a due consideration of *all* the essential and fundamental points of structure, wholly irrespective of external similarity of form and habits. Philosophical classification depends upon a due appreciation of what constitute the true points of difference and likeness amongst animals; and we have already seen that these depend essentially upon dissimilarity or similarity of morphological type. Philosophical classification, therefore, is a formal

expression of the facts and laws of Morphology. It follows that the more fully the programme of a philosophical and strictly natural classification can be carried out, the more completely does it afford a condensed exposition of the fundamental construction of the objects classified. Thus, if the whale were placed by an artificial grouping amongst the fishes, this would simply express the facts that its habits are aquatic and its body fish-like. When, on the contrary, we obtain a natural classification, and we learn that the whale is placed amongst the Mammalia, we then know at once that the young whale is born in a comparatively helpless condition, and that its mother is provided with special mammary glands for its support; this expressing a fundamental distinction from all fishes, and being associated with other equally essential correlations of structure.

Sound classification, therefore, depends in reality upon a correct discrimination between likenesses of homology and likenesses of analogy. Likenesses of analogy—that is, likenesses dependent solely upon the possession of organs discharging the same physiological function—are to be disregarded. Thus, the Bird and the Butterfly are not to be grouped together simply because both possess organs of flight. On the other hand, likenesses of homology—that is to say, likenesses dependent on identity of structural plan—are a safe guide to real affinity, enabling us to trace the genuine relationships which may subsist between animals outwardly very dissimilar, and affording to us the foundation of a common type capable of almost endless modification. Whilst the *theory* of philosophical classification is thus clear, it may be further said that great difficulties attend the carrying out of the admitted theory into actual *practice.* This arises chiefly from the difficulty which is met with when we come to disentangle the homological from the merely analogical likenesses of animals; and it is in overcoming this difficulty that a great portion of the labours of the philosophical zoologist consists.

The entire animal kingdom is primarily divided into some six or seven great plans of structure, the divisions thus formed being called "sub-kingdoms." The sub-kingdoms are, in turn, broken up into classes, classes into orders, orders into families, families into genera, and genera into species. We shall examine these successively, commencing with the consideration of a species, since this is the zoological unit of which the larger divisions are made up.

Species.—A "species" of animals may be defined as *an assemblage of individuals which resemble each other in their*

essential characters, are able, directly or indirectly, to produce fertile individuals, and which do not (as far as human observation goes) give rise to individuals which vary from the general type through more than certain definite limits. The production of occasional monstrosities does not, of course, invalidate this definition.

A "species," therefore, corresponds with what we should ordinarily understand as a "kind" of animals. Thus, all the Hedgehogs of Britain form one "species," all the Squirrels of Britain constitute a single "species," and so on. There are points connected with species, as to which naturalists are not yet in absolute agreement. All definitions of the term, however, involve two leading ideas—one of these being a certain amount of resemblance between individuals, and the other being the proof that the individuals so resembling each other have descended from a single pair, or from pairs exactly similar to one another. The characters in which individuals must resemble one another in order to entitle them to be grouped in a separate species, according to Agassiz, "are only those determining size, proportion, colour, habits, and relations to surrounding circumstances and external objects."

On a closer examination, however, it will be found that these two leading ideas in the definition of species—external resemblance and community of descent—are both defective, and liable to break down if rigidly applied. Thus, there are in nature no assemblages of plants or animals usually grouped together into a single species, the individuals of which *exactly* resemble one another in every point. Every naturalist is compelled to admit that the individuals which compose any so-called species, whether of plants or animals, differ from one another to a greater or less extent, and in respects which may be regarded as more or less important. The existence of such individual differences is attested by the universal employment of the terms "varieties" and "races." Thus a "variety" comprises all those individuals which possess some distinctive peculiarity in common, but do not differ in other respects from another set of individuals sufficiently to entitle them to take rank as a separate species. A "race," again, is simply a permanent or "perpetuated" variety. The question, however, is this—How far may these differences amongst individuals obtain without necessitating their being placed in a separate species? In other words: How great is the amount of individual difference which is to be considered as merely "*varietal*," and at what exact point do these differences become of "*specific*" value? To this question no answer can be given,

since it depends entirely upon the weight which different naturalists would attach to any given individual difference.[1] Distinctions which appear to one observer as sufficiently great to entitle the individuals possessing them to be grouped as a distinct species, by another are looked upon as simply of varietal value; and, in the nature of the case, it seems impossible to lay down any definite rules. To such an extent do individual differences sometimes exist in particular genera—termed "protean" or "polymorphic" genera—that the determination of the different species and varieties becomes an almost hopeless task.

Besides the individual differences which ordinarily occur in all species, other cases occur in which a species consists normally and regularly of two or even three distinct forms, which cannot be said to be mere varieties, since no intermediate forms can be discovered. When two such distinct forms exist, the species is said to be "dimorphic," and when three are present, it is called "trimorphic." Thus, in dimorphic plants a single species is composed of two distinct forms, similar to one another in all respects except in their reproductive organs, the one form having a long pistil and short stamens, the other a short pistil with long stamens. In trimorphic plants, the species is composed of three such distinct forms, which differ in like manner in the conformation of their reproductive organs, though they are otherwise undistinguishable (Darwin). Similar cases are known in animals, but in them the differences, though apparently connected with reproduction, are not confined to the reproductive organs. Thus the females of certain butterflies normally appear under two or three entirely different forms, not connected by any intermediate links; and the same thing occurs in some of the Crustacea.

As regards, therefore, the first point in the definition of species—namely, the external resemblance of assemblages of individuals—we are forced to conclude that no two individuals are exactly alike; and that the amount and kind of external resemblance which constitutes a species is not a precise and invariable quantity, but depends upon the value attached to particular characters by any given observer.

The second point in the definition of species—namely, community of descent—is hardly in a more satisfactory condition,

[1] As an example of this, it is sufficient to allude to the fact that hardly any two botanists agree as to the number of species of Willows and Brambles in the British Isles. What one observer classes as mere varieties, another regards as good and distinct species.

since the descent of any given series of individuals from a single pair, or from pairs exactly similar to one another, is at best but a probability, and is in no case capable of proof. In the case of the higher animals, it can doubtless be shown that certain assemblages of individuals possess amongst themselves the power of fecundation and of producing fertile progeny, and that this power does not usually extend to the fecundation of individuals belonging to another different assemblage. Amongst the higher animals, "crosses" or "hybrids" can only be produced between closely allied species, and when produced they are in general sterile, and are not capable of reproducing their like. In these cases, therefore, we may take this as a satisfactory element in the definition of "species." The sterility, however, of hybrids is not universal, even amongst the higher animals; and amongst plants no doubt can be entertained but that the individuals of species universally admitted to be distinct are capable of mutual fertilisation; the hybrid progeny thus produced being likewise fertile, and capable of reproducing similar individuals. That this fertility is often irregular, and may be destroyed in a few generations, admits of explanation, and hardly alters the significance of these undoubted facts.

In spite of the above-mentioned exceptions, it is the "physiological test" of mutual fertility which is usually adopted by naturalists in distinguishing between "varieties" and "species," —when, namely, the individuals of a given assemblage of animals or plants are fertile, and are capable of giving rise to fertile offspring, they are usually regarded as constituting a single "*species*," however widely they may differ among themselves in structure or appearance. "Varieties," therefore, are supposed to be always *capable* of interbreeding with the type-form of the species. On the other hand, if two groups of animals or plants, otherwise closely resembling each other, are found to be incapable of producing fertile offspring by intercrossing, then they are regarded as constituting *two* distinct species. While the mutual fertility of the individuals composing a species and a variety respectively is admitted, there are grounds for believing that the individuals composing a variety do not *habitually* mate with those composing the type-species. It is only upon some such supposition as this that we can account for the permanence of the variety, since free intercrossing with the parent-species would inevitably lead to the ultimate reabsorption of the former in the latter. Whether this reproductive isolation of the individuals composing a variety, in regard to those composing the parent-species, is the result of physical pecu-

liarities in the reproductive organs in the former (Romanes), or is due to modification of the normal sexual instinct (Galton), has not yet been determined.

Genus is a term applied to groups of species which possess a community of essential details of structure. A genus may include a single species only, in cases where the combination of characters which make up the species are so peculiar that no other species exhibits similar structural characters; or, on the other hand, it may contain an indefinite number of species.

Families are groups of genera which agree in their general characters. According to Agassiz, they are divisions founded upon peculiarities of "form as determined by structure."

Orders are groups of families related to one another by structural characters common to all.

Classes are larger divisions, comprising animals which are formed upon the same fundamental plan of structure, but differ in the method in which the plan is executed (Agassiz).

Sub-kingdoms are the primary divisions of the animal kingdom, which include all those animals which are formed upon the same structural or morphological type, irrespective of the degree to which specialisation of function may be carried.

BINOMIAL NOMENCLATURE.—Since the time of Linnæus it has been the practice of naturalists to designate all *species* by double designations, the first part of the title indicating the *genus* to which the animal belongs, whilst the second is the proper or *specific* title. Thus the Dog is known by the "binomial" designation of *Canis familiaris*. The "*genus*" *Canis* contains other species besides the Dog—such as the Wolf and Jackal—but the name *familiaris* indicates that this title belongs to the Dog and not to either of the latter. The genus *Canis*, again, belongs to the "*family*" *Canidæ*, including other genera, such as the Foxes (*Vulpes*). The family *Canidæ*, further, is one of a number of families, such as the Cats (*Felidæ*), the Bears (*Ursidæ*), the Hyænas (*Hyænidæ*), &c., which collectively constitute the "*order*" of the *Carnivora* or Beasts of Prey. The *Carnivora*, again, constitute one of many orders of quadrupeds, which are distinguished by suckling their young and by other common characters, and which collectively constitute the "*class*" *Mammalia*. Finally, the *Mammalia* are united with the classes of the Birds, Reptiles, Amphibians, and Fishes to constitute the great primary division or "*sub-kingdom*" of *Vertebrata* or "Vertebrate animals"; since all these classes agree with one another in certain fundamental points of structure.

Condensing the above, the name of *Canis familiaris*, as applied to the Dog, *implies* a large amount of information as to the precise zoological position and affinities of the animal. Its title, namely, if expressed in full, would indicate its systematic place to be as follows:—

Sub-kingdom, VERTEBRATA.
Class, *Mammalia*.
Order, *Carnivora*.
Family, *Canidæ*.
Genus, *Canis*.
Species, *Canis familiaris*.

Impossibility of a Linear Classification.—It has sometimes been thought that the animal kingdom can be arranged in a linear series, every member of the series being higher in point of organisation than the one below it. As we have seen, however, the *status* of any given animal depends upon two conditions—one its morphological type, the other the degree to which specialisation of function is carried. Now, if we take two animals, one of which belongs to a lower morphological type than the other, no degree of specialisation of function, however great, will place the former above the latter, as far as its *type of structure* is concerned, though it may make the former a more highly organised animal. Every Vertebrate animal, for example, belongs to a higher morphological type than every Mollusc; but the higher Molluscs, such as Cuttle-fishes, are much more highly organised, as far as their type is concerned, than are the lowest Vertebrata. In a linear classification, therefore, the Cuttle-fishes should be placed above the lowest fishes—such as the Lancelet—in spite of the fact that the type upon which the latter are constructed is by far the higher of the two.

It is obvious, therefore, that a linear classification is not possible; since the higher members of each sub-kingdom are more highly organised than the lower forms of the next sub-kingdom in the series, at the same time that they are constructed upon a lower morphological type.

It is, in fact, clear that a pictorial representation of the different groups of the animal kingdom, in the order of their natural alliances, would not exhibit a series of regularly ascending steps, but would have the form of a branched and ramified genealogical tree. Such a tree would exhibit one main stem, which would give origin to numerous lateral stems. These latter would, in turn, subdivide, some branches ascending in the course of their development, while others, as the result of degeneration, would descend.

10. Origin of Species.

It is impossible here to do more than merely indicate in the briefest manner the two fundamental ideas which are at the bottom of all the various theories as to the origin of species; and it will be sufficient to give an outline of the two leading theories which have been held upon this subject, without adducing any of the reasoning upon which they are based. It should be added, however, that almost all scientific men are at the present day agreed that species have been produced by a pro-

cess of evolution or development, though all are not agreed as to the manner in which that evolution has been carried out.

I. *Doctrine of the Fixity of Species.*—On this view of the nature of species, which may be said to have been generally held up to the middle of the present century,[1] it is held that "species" are essentially fixed and immutable. Although the older naturalists recognised the variability of species, they believed variation to be strictly limited and definite. Hence, though a species might oscillate backwards and forwards on both sides of a central line, it would, sooner or later, return to the position of equilibrium represented by the *type-form* of the species. Closely connected with the belief in the fixity of species is the belief in their "special creation." If "species" be permanent and immutable, then each must have come into existence at a particular moment of time and at a particular place in space. The place where the species originated can only have been that where the original progenitor, or progenitors, of the species appeared, and for such appearance no explanation can be given other than that of "special creation"—this being, obviously, one of those explanations which explains nothing. Each species, finally, was supposed to have slowly diffused itself by migration from its original "specific centre," till its further progress was stopped, in consequence of its no longer finding conditions suitable for the life of the species.

II. *Doctrine of the Mutability of Species.*—At the present day, it may be said that naturalists have generally, if not universally, abandoned the belief in the fixity of species, and in the doctrine of special creation. On the other hand, it is now generally admitted that species are not permanent and immutable, but that they "undergo modification, and that the existing forms of life are the descendants by true generation of pre-existing forms" (Darwin).

One of the first writers to promulgate definitely the theory of the mutability of species, and of their evolution from pre-existing forms, was Dr Erasmus Darwin,[2] the grandfather of Charles Darwin. At a somewhat later period, similar views were powerfully advocated, and explicitly set forth, by the great French naturalist Lamarck.[3] According to Lamarck's views, "species" are not absolutely fixed and constant, but they are only stable so long as their environment remains essentially unchanged. He held, further, that the existing species of

[1] In the year 1859, Darwin published the first edition of the Origin of Species by means of Natural Selection.

[2] Zoonomia, or the Laws of Organic Life (1794-96).

[3] Philosophie Zoologique (1809).

animals and plants had been produced by "evolution" from other pre-existing species—the course of evolution having been, on the whole, progressive. With regard to the causes which produce the slow modification of an existing species, and which, therefore, tend to give rise to a new species, Lamarck relied largely upon the action of external conditions. He regarded the organism as being in all cases more or less plastic, so that though it might exhibit an apparent fixity under fixed conditions, any gradual change in its environment would produce a corresponding alteration in the *structure* of the organism. Relying upon the facts established by geology as to the constantly changing conditions of all portions of the earth's surface, Lamarck concluded that all species of animals and plants must necessarily exhibit a corresponding mutability of form and structure. With regard to the method in which changes in the surrounding conditions might produce corresponding changes in the organisation of living beings, he relied principally upon the known effects of use and disuse upon organs. Upon the whole, therefore, he concluded that the existing fauna and flora of the world had been produced by the slow modification of pre-existing animals and plants consequent upon slow and progressive changes in terrestrial conditions.

The theory of the origin of "species" from pre-existing forms of life was first established upon a sound basis by Charles Darwin, who published in 1859 his great work on this subject.[1] In this work Darwin gave, for the first time, a scientifically satisfactory explanation as to the method in which the principle of evolution, previously brought forward by Erasmus Darwin, Lamarck, and others, might operate in the production of "species." This explanation is embodied in the "Theory of Natural Selection," which is based upon the following fundamental propositions :—

1. The progeny of all species of animals and plants exhibit variations amongst themselves in all parts of their organisation, no two individuals being exactly and in all respects alike. In other words, in every species the individuals, whilst inheriting a general likeness to their progenitors, tend by variation to diverge from the parent-type in some particular or other.

2. Variations arising in any part of the organism, however minute, may be transmitted to future generations, under certain

[1] In the same year (1859), Mr Alfred Russell Wallace published views as to the origin of species in many respects identical with those of Darwin, in an independently worked-out memoir, entitled "On the Tendency of Varieties to depart indefinitely from the Original Type" (Journ. Linn. Soc.)

definite and discoverable laws of inheritance, becoming, as a rule, intensified in course of transmission.

3. By "artificial selection," or by breeding from individuals possessing any particular variation, man, in successive generations, can produce a breed in which the variation will be permanent, the divergence from the parent-type being usually intensified by the process of interbreeding. The races thus artificially produced by men are often as widely different as are distinct species of wild animals.

4. The world in which all living beings are placed is one not absolutely unchanging, but is liable, on the contrary, to subject them to very varying conditions.

5. All animals and plants give rise to more numerous young than can by any possibility be preserved, each species tending to increase in numbers in a geometrical progression.

6. As these young are none of them exactly alike in all respects, a process of "natural selection" will ensue, whereby those individuals which possess any variation, however slight, favourable to the peculiarities of the life of the species, will tend to be preserved. Those individuals, on the other hand, which do not possess any such favourable variation, will be placed at a disadvantage in the "struggle for existence," and will tend to be gradually exterminated. The individuals, therefore, composing any species are thus subjected to a rigid process of sifting, by which those least adapted to their environment are being perpetually weeded out, whilst "the survival of the fittest" is secured.

7. Other conditions remaining the same, the individuals which survive in the struggle for existence will transmit the variations to which they owe their preservation to future generations, and these variations will tend to become gradually more and more pronounced.

8. By a repetition of this process, "varieties" are first established; these become permanent, and "races" are produced; finally, in the lapse of time, the differences thus caused become sufficiently marked to constitute distinct "species."

9. Granted a sufficient length of time since life first appeared upon the earth, it is conceivable that all the different animals and plants which we see at present upon the globe, may have been produced by the action of natural selection upon the offspring of a few primordial forms, or, it may be, of a single primitive being.

Originally, Mr Darwin appears to have believed that "natural selection" would alone be found sufficient to account for the origin of all existing species by a process of evolution from pre-existing forms. In

view, however, of certain objections which had been brought forward, Mr Darwin seems to have abandoned this position, and brought forward a cause supplementary to "natural selection" in what he termed "sexual selection." The action of sexual selection in a supposed process of evolution, according to Mr Darwin's views, may be stated in the following two propositions :—

a. The males of many species of animals are known to engage in very severe contests for the possession of the females, these latter yielding themselves to the victor. In such contests certain males will inevitably have certain advantages over the others, either in point of strength or activity, or in consequence of the possession of more efficient offensive weapons. There will therefore always be a probability that certain males will get possession of the females in preference to others : and thus there will be a tendency in the individuals of many species of animals to secure a preponderance of offspring from the strongest males. The peculiarities which enable certain males to succeed in these contests will, *cæteris paribus*, be transmitted to their male offspring, and in this way variations may be perpetuated, initiated, or intensified.

b. In the preceding cases, the females are believed to be perfectly passive, and the selection is a "natural" one, the final result depending solely upon the natural advantages which certain males possess over others in actual combat. It is alleged, however, that there are other cases in which the selection is truly "sexual," since its result is determined by spontaneous preference, and not by brute force alone. It is asserted, namely, that among certain species of animals, the females exercise a free choice as to the particular male with which they will pair ; the males being passive agents in the matter, except in so far as each uses, or may use, his utmost exertions to secure that the choice of the female may fall upon him. The circumstances supposed to influence, and ultimately determine, the choice of the female, are of course, in the main, the personal attractions of some particular male, the female being captivated by some "beauty of form, colour, odour, or voice," which such a male may possess.

If it be admitted that the females of some of the lower animals have the power of expressing and exercising a preference in the manner above indicated, then it is easy to understand how variations might be transmitted or intensified in this way. The male who is most attractive to the female will, other things being equal, have the best chance of propagating his species, and is likely to leave the largest number of descendants. His male offspring will inherit the peculiarities by which their sire was rendered pre-eminently attractive in the eyes of their mother, and thus a well-marked breed might be produced, by the preservation or intensification of characters of this nature. Mr Darwin is disposed to believe that colour and song in most, if not in all animals, are thus to be ascribed to the action of sexual selection, through numerous successive generations.

Of the many *objections* which have been urged against the theory of the origin of species by means of natural selection, the following are the most important :—

1. On the theory of natural selection, the organs possessed by an animal have been slowly evolved, and have not been produced suddenly, in complete perfection. Most, if not all, organs, therefore, must have been useless to their possessor in their early or incipient stage. Natural selection, however, has no power to preserve or intensify any structures except such as are *directly* useful to the individual in the struggle for existence.

2. Again, when a useful variation has appeared among the individuals of a species, there would be little probability of its being preserved, unless it should appear, "similarly and simultaneously," in a considerable number of individuals. If it appeared in a few individuals only, it would almost certainly be rapidly "lost by subsequent intercrossing with ordinary individuals." There is, however, no evidence to show that variations occur, as a rule at any rate, in more than a few individuals of a species in the first place.

To meet this difficulty, Dr Romanes has recently brought forward [1] a theory to which he has applied the name of "the theory of physiological selection," and which may be stated here in the briefest possible form. It is, of course, an undoubted fact that a variation which has appeared in even a few individuals may be preserved and handed down, provided the individuals which possess it are prevented from interbreeding with the parent form. This is effected, for example, when by the intervention of man, or in any other way, the varying individuals are kept apart from those composing the original species, so that they can interbreed with each other only, thus tending to perpetuate and intensify their distinctive peculiarities. It seems, also, to be a fact that, though the individuals of a variety are *capable* of interbreeding with the parent form, they do not do so as readily as they do with each other. In nature, according to the theory here in question, the varying individuals are supposed to be prevented from interbreeding with the parent stock in consequence of some slight change in their reproductive system, which renders them more or less sterile with the original species, though perfectly fertile among themselves. The result of this is, obviously, the same as if the varying individuals had been cut off from the normal individuals artificially, or by some geographical barrier. Being, namely, fertile with one another, and only partially so with the parent form, they naturally tend to hand down to their offspring their distinctive variations, and these tend in the course of transmission to become intensified. Upon the same hypothesis, it is also possible to meet the first-mentioned objection to the theory of natural selection, and to explain how *useless* variations may be preserved and handed down.

3. The only other objection to the theory of natural selection which need be mentioned here, is that we have no sufficient evidence of the former existence of the numerous and closely graduated transitional forms between different species, which must, on this theory, have existed. It is an essential part of the theory in question that the production of any given species from any pre-existing species can only have been effected through the intervention of a long series of intermediate or transitional forms. It is true that many extinct animals are known which are clearly transitional between existing groups now more or less widely separated from one another. So far, however, it cannot be denied that palæontology has failed to bring forward the numerous and *closely graduated* series of intermediate forms which must have at one time existed, supposing that the different species of animals and plants had been evolved by natural selection from pre-existing species. The absence of a sufficient number of such transitional forms, and the insufficient connection between such as are known to exist, may, doubtless, be in part explained by the known "imperfection of the geological record"; but this does not appear to offer an adequate solution of the difficulty.

In spite of the above-mentioned objections, it may be taken as certain that "natural selection" is, at any rate, *one* of the

[1] Journal of the Linnean Society, vol. xix., 1886.

agents concerned in the production of species, and that it is an important agent. There is, further, abundant evidence in favour of the general doctrine that species are mutable, and that they have been produced by some general law of evolution from pre-existing species, quite apart from the question as to the *mode* in which evolution has been brought about. Thus, all the varied types which form each of the great "sub-kingdoms" are built upon a common morphological plan. This underlying unity of structure is, however, quite inexplicable unless we suppose it to depend upon blood-relationship, and to be due to the fact that the members of each sub-kingdom have descended from a common ancestor. Again, transitional forms, which connect one sub-kingdom with another, are not unknown, thus pointing to the possibility that even the different sub-kingdoms may have originated in a single primordial form of life. It is, further, only upon the theory of descent from a common ancestor that we can explain the well-known fact that the adult animal often exhibits in its embryonic state structures which it loses when fully grown, but which are present throughout life in the adults of animals lower in the scale. Thus, the so-called "visceral clefts" of the Mammalian embryo are unquestionably homologous with the gill-slits of the adult Fish; and this can only be explained upon the supposition that both Mammals and Fishes have descended from a common ancestor, in which these structures existed. The presence of "rudimentary organs" or "vestiges" in so many adult animals can likewise only be sufficiently explained upon the supposition we have to deal in these with the relics of organs which existed in a fully-developed condition in an original ancestral type. Lastly, the fact that so many existent and now widely separated groups of animals can be shown to be connected together by transitional extinct forms, hardly admits of reasonable explanation save on some theory of the general evolution of existing types from pre-existent species. This consideration is not affected by the previously stated fact that the transitional forms in question are not sufficiently numerous, nor linked together with sufficient closeness, to lead us to think that "natural selection" has been the sole agent of evolution.

11. Reproduction.

Reproduction is the process whereby new individuals are generated and the perpetuation of the species ensured. The process may be considered as being, in many respects, a modification of growth. It has been previously seen that a single cell,

or independent mass of protoplasm, has the power of producing fresh cells, or masses similar to itself, by throwing out buds ("gemmation"), or by dividing itself ("fission"). If such a cell or mass of protoplasm constitutes the entire organism, then this production of new cells is its process of reproduction. If, on the contrary, such a cell is merely a single constituent of a multicellular organism or cell-aggregate, then the process is one of growth. What is ordinarily called "reproduction" differs, therefore, from ordinary growth principally in the fact that its products are separated from the producing body—it is *discontinuous* growth. What is termed "non-sexual reproduction" is, in fact, really only a form of continuous cell-multiplication, and it results in the production of "composite" or "colonial" organisms, such as the higher plants and many of the lower forms of animal life.

In what is called "sexual reproduction," on the other hand, the production of new beings is the result of the union or fusion of two masses of protoplasm, which may be derived from the same, or from different individuals. As the result of this fusion, the protoplasm, stimulated in some way by the process to which it has been subjected, undergoes division, and thus gives rise to one or more new beings. In one form of this process, which cannot strictly be spoken of as "sexual," the two uniting masses of protoplasm are themselves entire organisms. This occurs, for example, in the so-called "conjugation" of certain of the Infusorian Animalcules, when two cells—each constituting an entire animal—become completely fused with one another, the resulting mass of protoplasm subsequently breaking up into a number of masses, each of which becomes a new Infusorian. More usually, the two uniting masses of protoplasm are merely special cells, detached from the parent organism.

The more important phenomena connected with reproduction may be very briefly glanced at here, under the two following heads:—

I. *Sexual Reproduction.*—In its typical form this consists essentially in the production of two distinct elements, a germ-cell or ovum, and a sperm-cell or spermatozoid, by the contact of which the ovum—now said to be "fecundated"—is enabled to develop itself into a new individual. As a rule, the germ-cell is produced by one individual (female) and the spermatic element by another (male); in which case the sexes are said to be distinct, and the species is said to be "diœcious." In other cases the same individual has the power of producing both the essential elements of reproduction; in which case the

sexes are said to be united, and the individual is said to be "hermaphrodite," "androgynous," or "monœcious." In the case of hermaphrodite animals, however, self-fecundation—contrary to what might have been expected—rarely constitutes the reproductive process; and, as a rule, the reciprocal union of two such individuals is necessary for the production of young. Even amongst hermaphrodite plants, where self-fecundation may, and certainly does, occur, provisions seem to exist by which perpetual self-fertilisation is prevented, and the influence of another individual secured at intervals. Amongst the higher animals sexual reproduction is the only process whereby new individuals can be generated.

II. *Non-sexual Reproduction.*—Amongst the lower animals fresh beings may be produced without the contact of an ovum and a spermatozoid; that is to say, without any true generative act. The processes by which this is effected vary in different animals, and are all spoken of as forms of "asexual" or "agamic" reproduction ("agamogenesis"). As we shall see, however, the true "individual" is very rarely produced otherwise than sexually, and most forms of agamic reproduction are really modifications of growth.

a. Gemmation and Fission.—Gemmation, or budding, consists in the production of a bud, or buds, generally from the exterior, but sometimes from the interior, of the body of an animal, which buds are developed into independent beings, which may or may not remain permanently attached to the parent organism. Fission differs from gemmation solely in the fact that the new structures in the former case are produced by a division of the body of the original organism into separate parts, which may remain in connection, or may undergo detachment.

The simplest form of gemmation, perhaps, is seen in the power possessed by certain animals of reproducing parts of their bodies which they may have lost. Thus, the Crustacea possess the power of reproducing a lost limb, by means of a bud which is gradually developed till it assumes the form and takes the place of the missing member. In these cases, however, the process is not in any way generative, and the product of gemmation can in no sense be spoken of as a distinct being (or zoöid).

An excellent example, however, of true gemmation is exhibited in such an organism as the common Sea-mat (Flustra), which is a composite organism composed of a multitude of similar beings, each of which inhabits a little chamber or cell; the whole forming a structure not unlike a sea-weed in appear-

ance. This colony is produced by gemmation from a single primitive being (" polypide "), which throws out buds, each of which repeats the process, apparently almost indefinitely. All the buds remain in contact and connected with one another, but each is, nevertheless, a distinct and independent being, capable of performing all the functions of life. In this case, therefore, each one of the innumerable buds becomes an independent being, similar to, though not detached from, the organism which gave it birth. This is an instance of what is called " continuous gemmation."

In other cases—as in the common Fresh-water Polype or Hydra—the buds which are thrown out by the primitive organism become developed into creatures exactly resembling the parent, but, instead of remaining permanently attached, and thus giving rise to a compound organism, they are detached to lead an entirely independent existence. This is a simple instance of what is termed " discontinuous gemmation."

The method and results of fission may be regarded as essentially the same as in the case of gemmation. The products of the division of the body of the primitive organism may either remain undetached, when they will give rise to a composite structure (as in many corals), or they may be thrown off and live an independent existence (as in some of the Hydrozoa).

We are now in a position to understand what is meant, strictly speaking, by the term " individual." In zoological language, an *individual* is defined as " *equal to the total result of the development of a single ovum.*" Amongst the higher animals there is no difficulty about this, for each ovum gives rise to no more than one single being, which is incapable of repeating itself in any other way than by the production of another ovum; so that an individual is a single animal. It is most important, however, to comprehend that this is not necessarily or always the case. In such an organism as the Sea-mat, the ovum gives rise to a primitive polypide, which repeats itself by a process of continuous gemmation until an entire colony is produced, each member of which is independent of its fellows, and is capable of producing ova. In such a case, therefore, the term " individual " must be applied to the entire colony, since this is the result of the development of a single ovum. The separate beings which compose the colony are technically called zoöids. In like manner the Hydra, which produces fresh and independent Hydræ by discontinuous gemmation, is not an " individual," but a zoöid. Here the zoöids are not permanently united to one another, and the " individual " Hydra consists really of the primitive Hydra, *plus* all the detached

Hydræ to which it gave rise. In this case, therefore, the "individual" is composed of a number of disconnected and wholly independent beings, all of which are the result of the development of a single ovum. It is to be remembered that both the parent zoöid and the "produced zoöids" are capable of giving rise to fresh Hydræ by a true generative process. It must also be borne in mind that this production of fresh zoöids by a process of gemmation is not so essentially different from the true sexual process of reproduction as might at first sight appear, since the ovum itself may be regarded merely as a highly specialised bud. In the Hydra, in fact, where the ovum is produced as an external process of the wall of the body, this likeness is extremely striking. The ovarian bud, however, differs from the true gemmæ or buds in its inability to develop itself into an independent organism, unless previously brought into contact with another special generative element. The only exceptions to this statement are in the rare cases of true "parthenogenesis," to be subsequently alluded to.

b. Alternation of Generations.—In the case of the Hydra and the Sea-mat, which we have considered above, fresh zoöids are produced by a primordial organism by gemmation; the beings thus produced (as well as the parent) being capable not only of repeating the gemmiparous process, but also of producing new individuals by a true generative act. We have now to consider a much more complex series of phenomena, in which the organism which is developed from the primitive ovum produces by gemmation *two* sets of zoöids, one of which is destitute of sexual organs, and is capable of performing no other function than that of nutrition, whilst the other is provided with reproductive organs, and is destined for the perpetuation of the species. In the former case the produced zoöids all resembled each other, and the parent organism which gave rise to them; in the latter case, the produced zoöids are often very unlike each other and unlike the parent, since their functions are entirely different.

The simplest form of the process is seen in certain of the Hydroid Polypes, such as Hydractinia. The embryo of Hydractinia is a free-swimming ciliated body, which, after a short locomotive existence, attaches itself to some submarine object, develops a mouth and tentacles, and commences to produce zoöids like itself by a process of continuous gemmation. These remain permanently attached to one another, with the result that a compound organism is produced, consisting of a number of zoöids, or "polypites," organically connected together, but enjoying an independent existence. None of the zoöids,

however, are provided with sexual organs; and though there is theoretically no limit to the size which the colony may reach by gemmation, its buds are not detached, and the species would

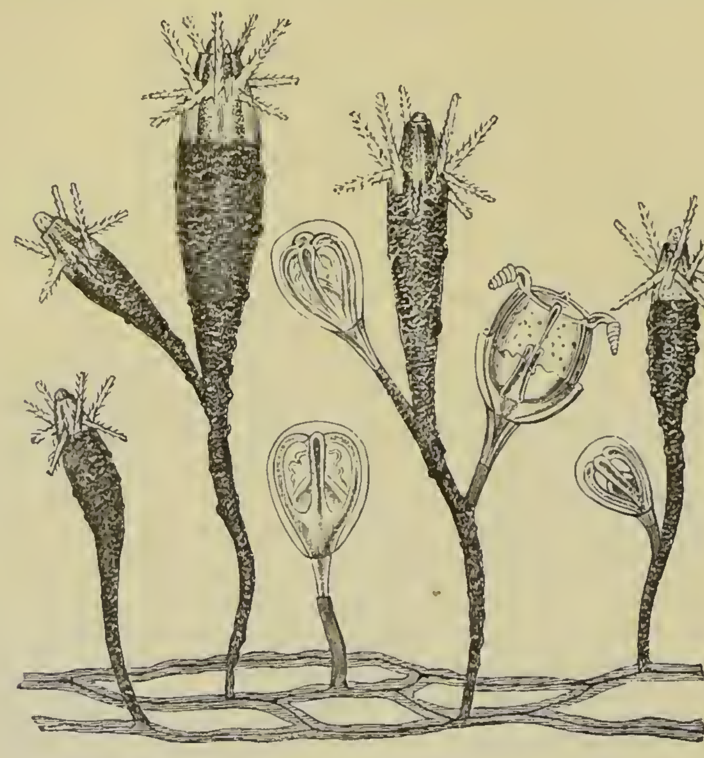


Fig. 11.—Part of the colony of *Perigonimus vestitus*, one of the Hydroid Zoophytes, greatly magnified. After Allman. The nutritive zoöids (polypites) carry a circle of tentacles; the reproductive zoöids (gonophores) are bell-shaped, and when fully mature are detached from the parent-colony.

therefore die out, unless some special provision were made for its preservation. Besides these nutritive zoöids, however, other buds are produced which differ considerably in appearance from the former, and which have the power of generating the essential elements of reproduction. These generative zoöids derive their nourishment from the materials collected by the nutritive zoöids, but only live until the ova are matured in their interior and liberated, when they disappear. The ova thus produced become free-swimming ciliated bodies, such as the one with which the cycle began.

In this case, therefore, the "individual" consists of a series of nutritive zoöids, collectively called the "trophosome," and another series of reproductive zoöids, collectively called the "gonosome," the entire series remaining in organic connection.

In other Hydroid Zoophytes allied to the preceding (such

as *Perigonimus*), the process advances a step further. In *Perigonimus* (fig. 11), the generative buds or zoöids do not produce the reproductive elements as long as they remain attached to the parent colony; but they require a preliminary period of independent existence. For this purpose they are specially organised, and when sufficiently mature they are detached from the stationary colony. The generative zoöid now appears as an entirely independent being, described as a species of Jelly-fish (or Medusa). It consists of a bell-shaped disc, by means of which it is enabled to swim freely; from the centre of this disc depends a nutritive process, with a mouth and digestive cavity, whereby the organism is able to increase considerably in size. The substance of the disc is penetrated by a complex system of canals, and from its margin hangs a series of tentacular processes. After a period of independent locomotive existence, the Medusa attains its full growth, when it develops ova and spermatozoa. By the contact of these, embryos are produced; but these, instead of resembling the jelly-fish by which they were immediately generated, proceed to develop themselves into the fixed Hydroid colony by which the Medusa was originally produced.

Still more extraordinary phenomena have been discovered in other Hydrozoa, as in many of the Acraspeda. In these the ovum gives rise to a locomotive ciliated body, which ultimately fixes itself, becomes trumpet-shaped, and develops a mouth and tentacles at its expanded extremity, when it is known as the "Hydra-tuba," from its resemblance to the Freshwater Polype, or Hydra. The Hydra-tuba has the power of multiplying itself by gemmation, and it can produce large colonies in this way; but it does not obtain the power of generating the essential elements of reproduction. Under certain circumstances, however, the Hydra-tuba enlarges, and, after a series of preliminary changes, divides by transverse fission into a number of segments, each of which becomes detached and swims away. These liberated segments of the little Hydra-tuba (it is about half an inch in height) now live as entirely independent beings, which were described by naturalists as distinct animals, and were called Ephyræ. They are provided with a swimming-bell, or "umbrella," by means of which they propel themselves through the water, and with a mouth and digestive cavity. They now lead an active life, feeding eagerly, and attaining in some instances a perfectly astonishing size (the jelly-fishes of some species are several feet in circumference). After a while they develop the essential elements of reproduction, and after the fecundation and liberation of their ova they

die. The ova, however, are not developed into the free-swimming and comparatively gigantic jelly-fish by which they were immediately produced, but into the minute, fixed, sexless Hydra-tuba.

We thus see that a small sexless zoöid, which is capable of multiplying itself by gemmation, produces by fission several independent locomotive beings, which are capable of nourishing themselves and of performing all the functions of life. In these are produced generative elements, which give rise by their development to the little fixed creature with which the series began.

To the group of phenomena of which the above are examples, the name "alternation of generations" was applied by Steenstrup; but the name is not an appropriate one, since the process is truly an alternation of generation with gemmation or fission. The only generative act takes place in the reproductive zoöid, and the production of this from the nutritive zoöid is a process of gemmation or fission, and not a process of generation. The "individual," in fact, in all these cases must be looked upon as a double being composed of two factors, both of which lead more or less completely independent lives, the one being devoted to nutrition, the other to reproduction. The generative being, however, is in many cases not at first able to mature the sexual elements, and is therefore provided with the means necessary for its growth and nourishment as an independent organism. It must also be remembered that the nutritive half of the "individual" is usually, and the generative half sometimes, *compound*—that is to say, composed of a number of zoöids produced by continuous gemmation; so that the zoological individual in these cases becomes an extremely complex being.

c. Parthenogenesis.—"Parthenogenesis" is the term employed to designate certain singular phenomena, resulting in the production of new individuals by virgin females without the intervention of a male. By Professor Owen, who first employed the term, parthenogenesis was applied also to the processes of gemmation and fission, as exhibited in sexless beings or in virgin females; but it is best to consider these phenomena separately. Strictly the term parthenogenesis ought to be confined to the production of new individuals from virgin females by means of *ova*, which are enabled to develop themselves without the contact of the male element. The difficulty in this definition is found in framing an exact definition of an ovum, such as will distinguish it from an internal gemma or bud. No body, however, should be called an "ovum" which does not

exhibit a germinal vesicle and germinal spot, and which does not exhibit the phenomenon known as segmentation of the yelk. Moreover, ova are almost invariably produced by a special organ, or ovary.

As examples of parthenogenesis, we may take the cases of the Plant-lice (Aphides), the Honey-bee, and certain Crustacea; though in the case of the first of these it is possible that the phenomena observed may admit of explanation otherwise than as an instance of parthenogenesis strictly so called.

The Aphides, or plant-lice, which are so commonly found parasitic upon plants, are seen towards the close of autumn to consist of male and female individuals. The ova produced by the females are now fertilised, and remain dormant through the winter. At the approach of spring these ova are hatched; but instead of giving rise to a number of males and females, all the young are of one kind, now usually regarded as peculiarly modified females. Whatever their true nature may be, these individuals produce, *viviparously*, a brood of young which resemble themselves; and this second generation, in like manner, produces a third,—and so the process may be repeated, for as many as ten or more generations, throughout the summer. When the autumn comes on, however, the viviparous Aphides produce—in exactly the same manner—a final brood, but this, instead of being composed entirely of similar individuals, is made up of males and females. Sexual union now takes place, and ova are produced and fecundated in the ordinary manner.

The viviparous Aphides are either wingless or winged; and the number of young produced is so great, that it has been calculated that a single Aphis might in this way be, during the summer months, and by the time the tenth generation was reached, the progenitor of no less than one quintillion of individuals. Each viviparous Aphis possesses an ovary, which only differs from that of the fertile females in being without certain secondary adjuncts (the colleterial glands and spermatheca). This "pseudovarium" produces egg-like bodies or "pseudova," which are directly developed into young Aphides, and which differ from true ova in the fact that they are incapable of fertilisation.

In the second case of alleged parthenogenesis which we are about to examine—namely, in the honey-bee—the phenomena which have been described appear to be quite free from doubt. A hive of bees consists of three classes of individuals: 1, a "queen," or fertile female; 2, the "workers," which form the bulk of the community, and are really undeveloped or sterile

females; and, 3, the "drones," or males, which are only produced at certain times of the year. We have here three distinct sets of beings, all of which proceed from a single fertile individual; and the question arises, In what manner are the differences between these produced? At a certain period of the year the queen leaves the hive, accompanied by the drones (or males), and takes what is known as her "nuptial flight" through the air. In this flight she is impregnated by the males; and in virtue of this single impregnation, she is enabled to produce fresh individuals for a lengthened period, the semen of the males being stored up in a receptacle which communicates by a tube with the oviduct, from which it can be shut off at will. The ova which are to produce workers (undeveloped females) and queens (fertile females) are fertilised on their passage through the oviduct, the semen being allowed to escape into the oviduct for this purpose. The subsequent development of these fecundated ova into workers or queens depends entirely upon the form of the cell into which the ovum is placed, and upon the nature of the food which is supplied to the larva. On the other hand, the ova which are intended to become males or drones are not allowed by the queen to come in contact with the spermatozoa in their passage through the oviduct. The drones, therefore, are produced from ova which have not been impregnated. The parthenogenetic origin of the drones is further proved by the fact, that if the queen be prevented from being impregnated by the males, she is only capable of producing drones. The workers, also, being undeveloped females, and quite incapable of being impregnated, are nevertheless known to occasionally produce eggs; and when this is the case, the eggs develop into drones. Lastly, in crosses between the common honey-bee and the Ligurian bee, the queens and workers alone exhibit any intermediate characters between the two forms, the drones presenting the unmixed characters of the queen by whom they were produced.

Among the Crustaceans, parthenogenesis has been established as occurring in some of the Water-fleas (*Cladocera*) and in various Phyllopods (*Apus*, *Limnadia*, *Artemia*, &c.). In these latter it is the female which is produced parthenogenetically; whereas in the honey-bee and in *Polistes* it is the male.

12. DEVELOPMENT.

Development is the general name applied to all those changes which an egg or germ undergoes before it assumes the characters of the perfect adult individual. In some cases these

changes are more or less completely concealed from view; in other cases they are largely external and visible. In some cases they are rapidly effected, and are but slight in amount; in other cases they may be more or less prolonged, and may more or less extensively alter the general form and mode of life of the animal. In these last-mentioned cases, the animal is usually said to pass through a "metamorphosis."

In the *Protozoa*, in which the organism does not rise above the condition of a simple cell, the phenomena of development are usually comparatively uncomplicated. In the *Metazoa*, in which the organism starts as a single cell, but ultimately becomes an aggregate of cells, the process of development is often one of extreme complexity. Speaking broadly, the course of development is, as Von Baer put it, *from the general to the special.* In other words, the changes undergone by any animal in passing from the embryonic to the mature condition are, in the main, changes in the direction of increased specialisation of functions and a correspondingly increased complexity of organic structure. All the members of any given sub-kingdom, when examined in their earliest embryonic condition, are found to exhibit an essential identity as regards their fundamental structure. As development proceeds, however, they diverge from one another with greater or less rapidity, until the adults become more or less widely unlike each other, the unlikeness being due to the different degrees of specialisation of functions necessary to perfect the adult.

It is upon a misconception of the true import of this law that the theory arose, that every animal in its development passed through a series of stages in which it resembles, in turn, the different inferior members of the animal scale. With regard to man, standing at the top of the whole animal kingdom, this theory has been expressed as follows: "Human organogenesis is a transitory comparative anatomy, as, in its turn, comparative anatomy is a fixed and permanent state of the organogenesis of man" (Serres). In other words, the embryo of a Vertebrate animal was believed to pass through a series of changes corresponding respectively to the permanent types of the lower sub-kingdoms—namely, the Protozoa, Cœlenterata, Echinodermata, Annulosa, and Mollusca—before finally assuming the true vertebrate characters. Such, however, is not truly the case. The ovum of every animal is from the first impressed with the power of developing in one direction only, and very early exhibits the fundamental characters proper to its sub-kingdom, never presenting the structural peculiarities belonging to any other morphological type. Nevertheless, the

differences which subsist between the members of each sub-kingdom in their adult condition are truly referable to the degree to which development proceeds, the place of each individual in his own sub-kingdom being regulated by the stage at which development is arrested. Thus, many cases are known in which the younger stages of a given animal *represent* the permanent adult condition of an animal somewhat lower in the scale. To give a single example, the young Frog transiently presents all the essential characters which permanently distinguish an adult perennibranchiate Amphibian, such as the Axolotl.

Not only is the embryo in many cases extremely unlike the adult animal, but there are many cases in which the former has a habitat and mode of life entirely different to those suitable to the latter. The adult, for example, may be a terrestrial, air-breathing animal, while the early stages of development may be passed in water. In such cases, it commonly happens that the embryo possesses "provisional" organs, which adapt it for its temporary mode of life, but which would be of no use to the adult. Such embryonic organs are in general either absorbed or modified in the course of development; the adult either showing no traces of their former existence, or exhibiting "vestiges" of them in the form of "rudimentary organs."

Ordinarily speaking, the course of development is an ascending one, and the adult is more highly organised than the young animal; but there are cases of a reversal of this law, the mature organism being, as compared with the embryo, a degraded form—except that it possesses the reproductive organs which are wanting in the latter. There are many cases, namely, in which the embryo is freely locomotive, and is provided with organs of sense, while the adult may be permanently fixed, and may entirely lose its sense-organs. This phenomenon of "*retrogressive development*" is seen in its extreme form in many "parasites"; that is to say, in animals which live at the expense of some other organism. In other cases, however, the retrogression may not be the result of parasitism, but may be simply due to the sedentary habit of life of the adult.

Viewing development as a whole, the process may be regarded as a repetition in the individual of the ancestral history of the animal—that is, of the history of the changes which the *species* has passed through before assuming its present characters. Certain stages in this history are, however, often either dropped out altogether in the development of the individual, or much abbreviated. This view of the significance of the process of development has been thus expressed by

Professor Haeckel. "Ontogenesis" (or the development of the individual) "is the brief and rapid recapitulation of phylogenesis" (or the development of the species) "governed by the physiological functions of transmission (reproduction) and nutrition (adaptation). The organic individual, during the rapid and brief course of its individual development, repeats the most important of those changes of form which its ancestors have passed through during the long and gradual course of their palæontological development, in accordance with the laws of transmission and adaptation."

13. Distribution in Space.

The *geographical* distribution of animals is concerned with the determination of the areas within which every species of animal is at the present day confined. Some species are found almost everywhere, when they are said to be "cosmopolitan"; but, as a rule, each species is confined to a limited and definite area. Not only are species limited in their distribution, but it is possible to divide the globe into a certain number of geographical regions or "zoological provinces," each of which is characterised by the occurrence in it of certain associated forms of animal life.

The geographical distribution of land animals is conditioned partly by the existence of suitable surroundings, and partly by the presence of barriers preventing migrations. Thus, certain contiguous regions might be equally suitable for the existence of the same animals, but they might belong to different zoological provinces, if separated by any impassable barrier, such as a lofty chain of mountains. Owing to their power of flight, the geographical distribution of birds is much less limited than that of mammals; and many migratory birds have an extremely wide range. In spite of their powers of locomotion, however, birds are limited by the necessities of their life to definite areas, and a zoological province is marked by its birds just as well as by its quadrupeds.

Each species of animals may be considered as having a "centre of distribution," where it attains its maximum development as regards the number of its individuals. From this centre the species ranges over a larger or smaller area, its numbers becoming less and less as we approach the borders of the area. The size of the area which the species will ultimately occupy—varying from a couple of square miles to hundreds of thousands of square miles—depends upon the presence of conditions suitable to the life of the species. The

three most important conditions are connected with the presence of a suitable food-supply, the existence of a suitable mean temperature, and the absence of an overwhelmingly powerful competing species. According as these or other necessary conditions may change, the area occupied by the species is liable to change from time to time, becoming contracted at one time, and then at another time being widely extended. The slowly produced secular changes in the climate and physical geography of different regions, which geology shows us to have been constantly going on since the earth was first tenanted by living beings, are, of course, the principal agents in determining the geographical distribution of animals at any given period. The extension of a species from one point to another is effected by migration. In many cases, the migration is effected by the adult, which is endowed with the power of locomotion. In the case of sedentary animals, however, migration is carried out through the locomotive young.

At the present day, naturalists usually adopt the arrangement of the dry land into zoological provinces, which was originally proposed by Mr Sclater. In this arrangement the earth's surface is divided into the following six provinces, each of which is characterised partly by the presence of a particular "fauna," or characteristic assemblage of animals, and partly by the absence of certain other characteristic animals:—

I. The *Palæarctic Province*, including Europe, Africa north of the Atlas Mountains, and Northern Asia. Among the more characteristic animals of this province are Bears, Sheep, Goats, Catarhine Monkeys, and Pheasants.

II. The *Ethiopian Province*, including Africa south of the Atlas Mountains, and Southern Arabia. Among the more characteristic animals are the African Elephant, the Hippopotamus, Giraffe, Hyrax, Aardvark, numerous Antelopes, Baboons, the Lion, and the Ostrich. There is a characteristic absence of Bears, Deer, Goats, and Sheep.

III. The *Oriental* or *Indian Province*, including Asia south of the Himalaya Mountains, Burmah, Siam, Southern China, and the Indian Archipelago (Java, Sumatra, Borneo, &c.). Characteristic animals are the Chevrotains, Indian Buffalo, Indian Elephant, Tiger, Hornbills, Pea-fowl, and Jungle-fowl.

IV. The *Australian Province*, including Australia, Tasmania, New Guinea, New Zealand, and most of the islands of the Pacific Ocean. Characteristic animals are the Duck-mole and Spiny Ant-eater (*Echidna*), numerous Marsupials, Birds of Paradise, Cockatoos, and the Australian Mud-fish (*Ceratodus*). There is a remarkable absence of most orders of the Placental

Mammals, of Vultures, Woodpeckers, and Tailed Amphibians. New Zealand is peculiar in not having any Marsupials nor Monotremes; in having no Reptiles except Lizards; and in the possession of the curious *Apteryx* and the extinct *Dinornis*.

V. The *Nearctic Province*, including North America down to the centre of Mexico. Characteristic animals are the Prong-buck, the Musk-rat, the American Buffalo, Tree-Porcupines, and the Turkey. The Beaver, Reindeer (Caribou), Sheep, and Bears are types common to this and the Palæarctic Region.

VI. The *Neotropical Province*, including the whole of South America, Central America, and Southern Mexico, together with the Antilles. Characteristic animals are the Platyrhine Monkeys, Llamas, Peccaries, Cavies, Sloths, Ant-eaters, Armadillos, Trogons, and Curassows. There is an absence of Insectivorous Mammals, Goats, Antelopes, Oxen, Cranes, &c. The Opossums are common to this and to the Nearctic Province.

The Fauna of Oceanic Islands.—Islands in the open ocean, far from land, are usually characterised by certain remarkable zoological features as compared with the continents, or with islands close to the continents. The most remarkable of these features are the following:—

1. Oceanic islands have comparatively few species of animals, as compared with an equal area of continental land.

2. On the other hand, an extraordinarily large proportion of the species are peculiar or "endemic."

3. Oceanic islands are remarkable for the number of species of terrestrial Molluscs which they possess, and for the large proportion of these which are peculiar to the islands in which they occur.

4. Terrestrial Mammals are few in number or wanting, and such indigenous species as may be present are usually of small size.

Bathymetrical Distribution.—In the ocean, as upon the land, animals are distributed according to more or less definite laws. There are, therefore, marine zoological provinces, as there are terrestrial ones,—particular tracts of the ocean being, in all regions, adapted for the life of peculiar types of animals. Thus, many marine animals abound especially in those portions of the sea-shore which lie between tide-marks, and which are therefore uncovered twice a-day by the retreating tide. This tract of the ocean-bed, between high and low water-mark, is termed the "Littoral Zone"; and in all countries it is characterised by the prevalence of particular groups of marine animals, which have their maximum development in this zone, or may be exclusively confined to it. Below low-water mark down to depths of about 15 fathoms, the great Tangle (*Laminaria*) flourishes in profusion, giving food and

shelter to innumerable types of marine life. This tract of the ocean-bed is often spoken of as the "Laminarian Zone." Beyond the Laminarian zone are other regions of different depths, which can often be recognised more or less clearly by the animals which inhabit them, and which have been indicated by special names. Thus, the "Coralline Zone" extends from 15 to 50 fathoms, and the name of "Deep-sea Coral Zone" has been given to the tract of the ocean-bed between 50 and 100 fathoms in depth.

The older naturalists believed that at depths greater than about 300 fathoms, animal life became extremely scanty in the sea, or disappeared altogether. It is now known, however, through the researches of Carpenter, Wyville Thomson, Gwyn Jeffreys, Wallich, Sars, Pourtales, A. Agassiz, and many other investigators, that the "deep sea," properly so called, extending from a depth of 300 fathoms down to depths of 3000 or 4000 fathoms, is tenanted by a vast number of animals, constituting a very remarkable and peculiar life-assemblage. The preponderating groups among these deep-sea or "abyssal" animals are the Foraminifera, the Radiolarians, the Siliceous Sponges, and the Echinoderms; but there are deep-sea representatives of almost all the groups of marine animals. Except in very limited depths, it seems, further, certain that the distribution of marine animals is mainly conditioned not by the *depth* of the water, but by its *temperature*. Similar types of marine life are, therefore, found inhabiting areas in the deep sea in which the bottom-temperature is the same, irrespective of what the precise depth of the water may be. It may also happen that two neighbouring areas of the sea-bottom may be inhabited by different assemblages of animals, in spite of their being close together, provided one area is swept by a current of warm water, while the other has its temperature lowered by an influx of cold bottom-water.

Lastly, we may regard the surface-layer of the open ocean, from the actual surface to depths of a few fathoms, as constituting another special zone of marine life. The animals inhabiting this zone are often spoken of as "pelagic" or "oceanic" animals, and they are often more or less delicate and gelatinous in texture, often translucent or transparent, and sometimes brightly coloured. Among the more striking groups of pelagic animals may be mentioned the *Foraminifera*, the Oceanic *Hydrozoa*, and the Pteropods; but many other groups possess pelagic representatives. These oceanic animals constitute one of the principal sources of food of the deep-sea

animals, their bodies after death ultimately falling to the bottom of the sea. The mud at the bottom of the deep sea is also commonly largely composed of the accumulated skeletons of these pelagic types of life (*Foraminifera*, *Radiolaria*, &c.). With regard to the great mass of water which lies between the surface-layer just spoken of and the bottom of the deep sea, our actual knowledge is still imperfect; but there seems to be reason to think that in it animal life is either very sparingly developed, or is wholly wanting.

14. Distribution in Time.

The distribution of animals in time, or their "geological distribution," constitutes a special branch of Zoological Science, to which the name of *Palæontology* is given. The laws of distribution in *time* are, however, from the nature of the case, much less perfectly known than are those relating to the distribution of animals in *space;* and it is only possible here to indicate some of the elementary considerations relating thereto.

In the first place, Geology shows us that a very large portion of the crust of the earth is composed of rocks which existed originally in the form of sand, mud, clay, or calcareous ooze, and which were laid down at the bottom of the sea. Other rocks, of a similar mineral nature, can be shown to have been originally formed by lakes or rivers; and there are also rocks which can be proved to have once been land-surfaces or soils. All these various kinds of rocks are more or less clearly divided into layers, or are "*stratified.*" These various kinds of rock, in the second place, often contain in their interior what are called "fossils" or "petrifactions," — in other words, the remains or traces of animals and plants which lived at the time when the rocks were in actual process of formation. In rocks which have been formed in the sea, the fossils consist chiefly of the skeletons of shell-fish, corals, sea-urchins, and other marine animals; in rocks which have been formed in lakes or rivers, we have chiefly fresh-water shells and the skeletons of fresh-water fishes; and in ancient soils we find the remains of plants, along with air-breathing animals, such as insects, spiders, or quadrupeds.

By means of these fossils we can not only determine the mode of origin of any particular stratified rock, but it is also possible to divide the entire series of stratified deposits into definite and chronologically successive groups of strata, which are technically called "formations." Each of these rock-

groups, or "formations," is characterised by the occurrence of an assemblage of fossil remains more or less peculiar to itself. Each "formation," therefore, corresponds with a particular *period* in the history of the earth—the rocks of the formation representing part of the marine, lacustrine, fluviatile, or terrestrial deposits of the period; and the fossils of the formation presenting to us part of the animals and plants which lived at the same period.

The majority of the animals of which the remains are now found in the rocks of the earth's crust, are "extinct," and belong to types no longer in existence. In the older formations, not only are all the animals extinct, but they differ widely from the types now in existence, and the older the formation, the greater is this unlikeness. On the contrary, in the more modern formations, the animals approximate more and more closely to existing types in their general characters. Ultimately, in the latest-formed rock-groups, we begin to meet with animals now actually in existence, along with many forms which are extinct. In still later formations, the number of extinct species is found to gradually diminish, and the number of species still living to gradually increase, till we reach the "recent" period, in which none of the animals (save such as have been exterminated by man) are extinct.

Though many extinct animals are so peculiar that they have to be placed in distinct families or orders, there is at present no known fossil which cannot be referred to one or other of the existing *sub-kingdoms*. So far as our present knowledge goes, we have, therefore, no proof of the former existence and disappearance of any primary "morphological type."

All the great morphological types of the *Invertebrata* are represented in the earlier periods of the earth's history, and their remains are found in the oldest fossiliferous formations. The Vertebrates appear later than the Invertebrates; and in both great sections of the animal kingdom there is traceable a gradual *progression* as we proceed from older to later formations, higher and higher zoological types appearing as we approach the recent period. There is, however, a great difference in this respect as regards different types of life; some having suffered a very early extinction, or having been introduced only in very late periods, while other so-called "persistent" types (such as *Nautilus* and *Lingula*) appeared at an extremely early period, and are still represented by living forms. Lastly, many extinct species of animals belong to what have been termed "intercalary" or "synthetic" types, since they exhibit characters intermediate between existing

groups of animals. The study of such types has a peculiar zoological interest, as they afford a means of bridging over the gap between groups now widely separated, and indicate the true line of descent of our existing species of animals.

In accordance with the laws above indicated, the fossiliferous rock-formations which compose the crust of the earth may be divided into four great series, termed respectively Archean, Palæozoic or Primary, Mesozoic or Secondary, and Kainozoic or Tertiary.

The Archean period is represented by the most ancient of the stratified deposits, and the rocks of this period are not only for the most part highly crystalline in their character, but they have not hitherto yielded any undoubted remains of animals or plants.

The Palæozoic or Ancient-life period is represented by the oldest of the fossiliferous formations, and is characterised by the marked divergence of the life of the period from all existing forms.

In the Mesozoic or Middle-life period, the general *facies* of the fossils approaches more nearly to that of our existing fauna and flora; but—with very few exceptions—the characteristic fossils are all specifically distinct from all existing forms.

In the Kainozoic or New-life period, the approximation of the fossil remains to existing living beings is still closer, and some of the forms are now specifically identical with recent species; the number of these increasing rapidly as we ascend from the lowest Kainozoic deposit to the Recent period.

Appended is a table giving the more important subdivisions of the four great geological periods, commencing with the oldest rocks and ascending to the present day (fig. 12).

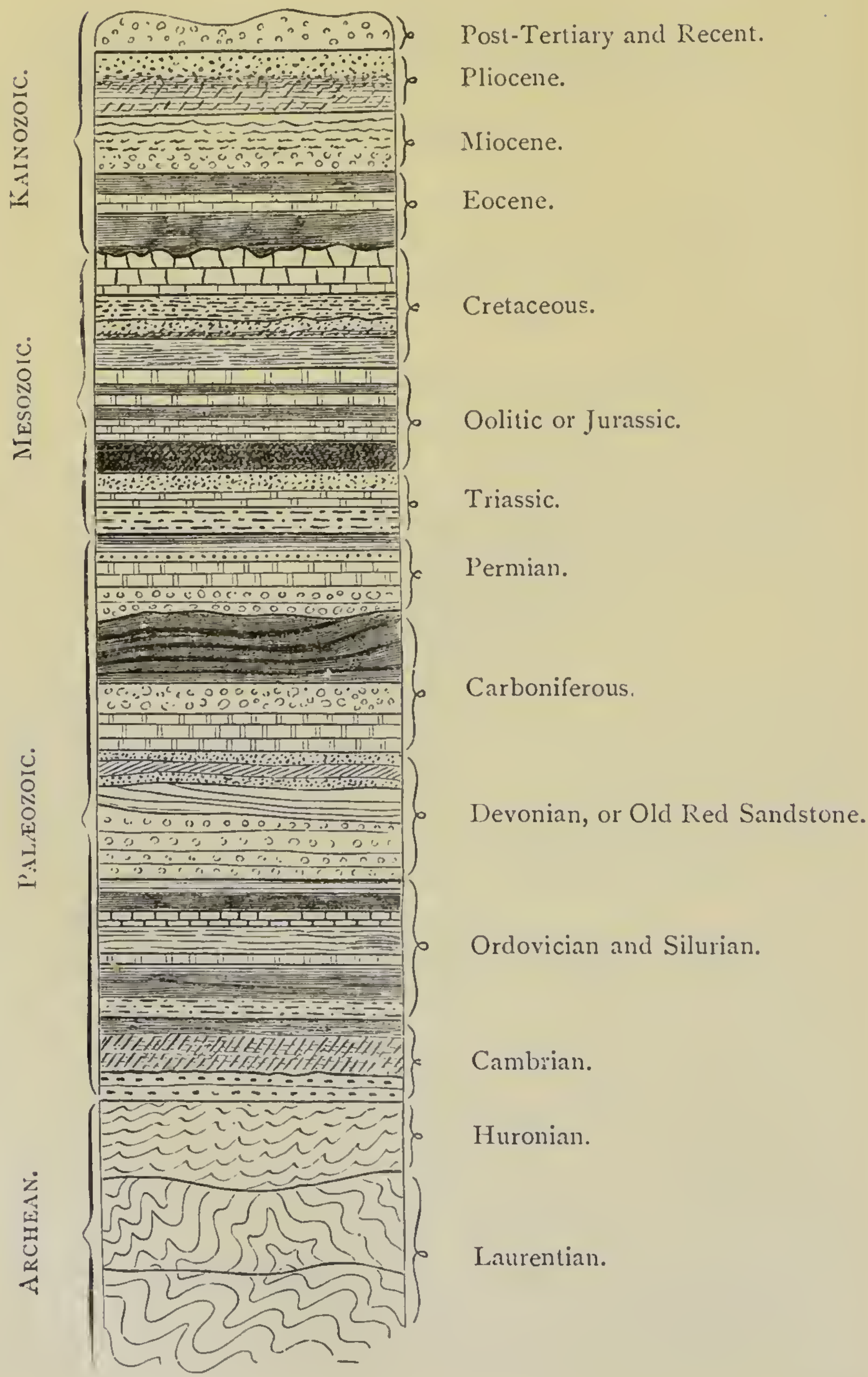
I. Archean Rocks. (Laurentian Rocks, Dimetian Rocks, Pebidian Rocks, &c.)

II. Palæozoic Rocks.

1. Cambrian. (Lower and Upper.)
2. Ordovician.
3. Silurian.
4. Devonian, or Old Red Sandstone. (Lower, Middle, and Upper.)
5. Carboniferous. (Mountain-limestone, Millstone-grit, and Coal-measures.)
6. Permian. (= the lower portion of the New Red Sandstone.)

IDEAL SECTION OF THE CRUST OF THE EARTH.

Fig. 12.



III. Mesozoic or Secondary Rocks.

7. Triassic Rocks. (Bunter Sandstein, or Lower Trias; Muschelkalk, or Middle Trias; Keuper, or Upper Trias; Rhætic beds.)

8. Jurassic Rocks. (Lias, Inferior Oolite, Great Oolite, Oxford Clay, Coral Rag, Kimmeridge Clay, Portland Stone, Purbeck beds.)

9. Cretaceous Rocks. (Wealden, Lower Greensand, Gault, Upper Greensand, White Chalk, Maestricht beds.)

IV. Kainozoic or Tertiary Rocks.

10. Eocene. (Lower, Middle, and Upper.)
11. Miocene. (Lower and Upper.)
12. Pliocene. (Older Pliocene and Newer Pliocene.)
13. Post-tertiary. (Post-pliocene and Recent.)

INVERTEBRATE ANIMALS.

PROTOZOA.

CHAPTER I.

1. General Characters of the Protozoa. 2. Classification. 3. Gregarinidæ.

1. *General Characters.*—The sub-kingdom *Protozoa*, as the name implies, includes the most lowly organised members of the animal kingdom, and may be defined as comprising *animals composed of undifferentiated protoplasm, or, at most, of protoplasm so far differentiated as to have developed an outer "wall" and a central "nucleus," the organism in the latter case becoming a "cell." In no case are definite "tissues" developed by the differentiation of a primitive cellular aggregate. There is no proper "body-cavity"; no nervous system; and either no alimentary apparatus, or one of a most rudimentary nature. Sexual reproduction, by means of ova and spermatozoa, is not known to occur.*

As has been already pointed out, the entire animal kingdom may be divided into the two primary sections of the *Protozoa* and the *Metazoa*—the former comprising animals which are essentially unicellular, or consist of simple undifferentiated protoplasm ("cytodes"), while the latter are multicellular, and commonly have their cells differentiated to form definite "tissues." On this view, the Sponges, which have been often associated with the *Protozoa*, must be placed in the section of the *Metazoa*.

The *Protozoa* are for the most part aquatic in their habits, and are generally of microscopic size. They are composed of contractile, jelly-like, or semi-fluid protoplasm, to which the

name of "sarcode" is commonly applied. The protoplasm of the outer layer of the body is often comparatively firm in texture, and clear or hyaline in aspect ("ectoplasm"); while the central portion of the body is composed of more fluid protoplasm ("endoplasm"), in which are developed numerous minute granules, probably of a fatty nature. In many cases the protoplasm is not surrounded by a definite outer envelope or wall, and has no "nucleus," thus permanently remaining in the condition of a mere "cytode." In other cases, there is developed in the protoplasm a definite solid or vesicular central body or "nucleus," and an outer "wall" is also present, the organism thus constituting a "cell."

As a rule, the protoplasm of the *Protozoa* contains more or less numerous circular clear spaces, which are filled with a watery fluid, and are termed "vacuoles." These may be very minute, or may be of large size, and they are not only not furnished with a definite wall, but are only temporary and variable in position. They are, in fact, mere spaces in the protoplasm, occupied either by water or by the fluids formed in the process of digestion. In many cases, there may be observed in addition one or two clear spaces in the protoplasm, which, though without walls, differ from the ordinary vacuoles in being permanent in position, and in opening and closing at intervals. These are the so-called "contractile vesicles" or "pulsating vacuoles," and they have been shown, in some cases, to give out radiating tubes into the surrounding protoplasm, and to communicate with the exterior. They are probably excretory in function, though they have been looked upon as a rudimentary form of circulatory organs.

There are no traces of a proper nervous system in any of the *Protozoa;* though structures which may possibly be of the nature of sense-organs are sometimes present. Food is taken into the body by simple absorption through the general surface, by means of "pseudopodia," or, in the higher forms, by a distinct external opening or mouth. From the presence or absence of a mouth the *Protozoa* have sometimes been divided into the two sections of the "stomatode" and "astomatous" *Protozoa;* but the distinction is one of little value. Beyond a mouth, and sometimes a short gullet, no differentiated alimentary organs exist in any *Protozoön.* No proper reproductive organs exist, and ova and spermatozoa are therefore not produced by any member of the sub-kingdom. Reproduction is generally effected by cleavage ("fission"), with or without previous "conjugation" of two individuals.

In a few of the *Protozoa* contractile fibres, which may be

compared with the muscles of the higher animals, are developed. The most characteristic organs of locomotion among the *Protozoa* are, however, "pseudopodia," or, in other words, prolongations of the sarcode, which can be thrown out from a part or from the whole of the surface, and which can be again retracted and withdrawn in the general body-substance. In other cases, locomotion is effected by the microscopic hair-like processes known as "cilia," which have the power of lashing to and fro or vibrating with great rapidity. Sometimes the cilia are accompanied or replaced by long whip-like contractile processes, which act in the same way, and which are known as "flagella."

The protoplasm may be destitute of any hard structures, or may have the power of developing an internal or external skeleton, generally composed of lime or flint, and often of a very complicated and mathematically regular form.

2. *Classification of the Protozoa.*—The sub-kingdom *Protozoa* is divided into three classes—viz., the *Gregarinidæ*, the *Rhizopoda*, and the *Infusoria*. In the Infusoria only is a mouth present, and hence these are sometimes spoken of as the "*Stomatode*" *Protozoa*, whilst the two former classes collectively constitute the "*Astomata*." Many of the Infusorians, however, have no mouth.

The following is a tabular view of the divisions of the *Protozoa*:—

Class I. GREGARINIDÆ.

Class II. RHIZOPODA.

Order 1. *Monera.*
,, 2. *Amœbea.*
,, 3. *Foraminifera.*
,, 4. *Radiolaria.*
,, 5. *Heliozoa.*

Class III. INFUSORIA.

Order 1. *Suctoria.*
,, 2. *Ciliata.*
,, 3. *Flagellata.*

3. CLASS I. GREGARINIDÆ.—The *Gregarinidæ* may be defined as *Protozoa in which the body has the form of a simple cell, without any mouth-aperture, and destitute of the power of emitting pseudopodia. The surface is not provided with cilia, flagella, or contractile filaments.* This class comprises minute

or microscopic animals, which are for the most part parasitic in their habits, and which are found in the alimentary canal or internal organs of both Invertebrate and Vertebrate animals. They are especially abundant as parasites of certain insects, Crustaceans, or worms. Rarely they are external parasites, or are found in decayed wood.

Anatomically, an adult Gregarine (fig. 13 B, and fig. 14 *b*)

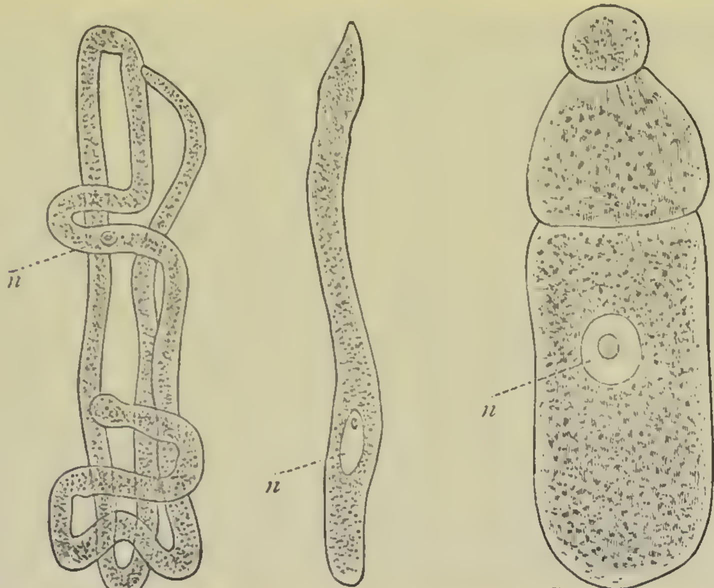


Fig. 13.—Gregarinidæ. A, *Gregarina gigantea*, parasitic in the Lobster, enlarged, after Van Beneden. B, *Monocystis magna*, parasitic in the Earth-worm, enlarged. C, An immature individual of *Gregarina blattarum*, greatly enlarged, after Bütschli, showing the separation of the body into an anterior, middle, and posterior portion: *n* Nucleus.

has the form of a simple cell, consisting of an ill-defined membranous envelope filled with more or less granular sarcode with fatty particles, and sometimes differentiated into a distinct contractile "cortical layer," which contains in its interior a vesicular nucleus, this in turn enclosing a solid particle, or nucleolus. In some the body exhibits an approach to a more complex structure by the presence of one or two transverse internal septa (fig. 13 C, and fig. 14 *a*); and a separate order has been founded for the reception of such under the name of *Dicystidea*, the simpler forms being grouped together under the name of *Monocystidea*. As regards their size, Gregarines vary from purely microscopic dimensions up to a length of about half an inch. The cell which constitutes the body is usually elongated, and the larger forms look, therefore, like

small worms. The cuticle with which the protoplasmic body is enclosed may be smooth, or striated, or may carry minute hair-like processes. Sometimes one end of the body is furnished with hooked processes (fig. 14 *a*), the function of which is to attach the parasite to the epithelial lining of the alimentary canal of its host. No differentiated organs of any kind, beyond the nucleus and nucleolus, exist, and both as-

Fig. 14.—Morphology and development of *Gregarinidæ* (after Stein and Lieberkühn). *a Stylorhynchus oligacanthus*, a "dicystidean" Gregarine; *b* Gregarine of the earth-worm ("monocystidean"); *c* The same encysted; *d* Further stage of the same, with the contents divided into "pseudonavicellæ"; *e* Free "pseudonavicellæ"; *f* Amœbiform mass of protoplasm liberated from a pseudonavicella; *g* and *h* Active forms of *f*. All the figures are greatly enlarged.

similation and excretion are performed by the general surface of the body. Though there are no pseudopodia, the body is contractile, and slow movements can be effected. Reproduction is effected by fission of the protoplasm of the body, either in a single individual or in two individuals which have become fused together, the fission being preceded by a quiescent stage in which the protoplasm surrounds itself in a membranous capsule or cyst.

The following is the general sequence of phenomena observed in the reproduction of the Gregarines, these phenomena occurring sometimes without apparent cause, or sometimes resulting from the apposition and coalescence of two individuals. In some species conjugation is invariable; in others it never occurs; and it may take place either by analogous or by opposite extremities. The *Gregarina*—or it may be two individuals which

have come into contact and adhered together—assumes a globular form, becomes motionless, and develops round itself a structureless envelope or cyst, when it is said to be "encysted" (fig. 14, *c*). The central nucleus then disappears, apparently by dissolution, whereupon the granular contents of the cyst break up into a number of little rounded masses, which gradually elongate and become lanceolate, when they are termed "pseudonavicellæ" (or "pseudonaviculæ," fig. 14, *d*). The next step in the process consists in the liberation of the pseudonavicellæ, which escape by the rupture of the enclosing cyst (fig. 14, *e*). If they now find a congenial habitat, they give origin to little sarcodic masses, which exhibit lively movements, and are endowed with the power of throwing out and retracting little processes of the body which closely resemble the "pseudopodia" of the *Rhizopoda;* so that the pseudonavicella in this condition is very similar to an adult *Amœba* (fig. 14, *f*, *g*, *h*). Finally, these amœbiform bodies are developed into adult *Gregarinæ*. In other cases, the contents of the pseudonavicella are converted in part into sickle-shaped rods, which ultimately give rise to adult Gregarines. It will be seen from the above that the formation of the pseudonavicellæ out of the granular contents of the body, subsequent to the disappearance of the nucleus, presents a close analogy to the segmentation of the impregnated ovum which follows upon the dissolution of the germinal vesicle. In *Gregarina gigantea* of the Lobster the embryo is a little mass of sarcode, quite like an *Amœba* except that it wants a nucleus and contractile vesicle. It soon gives out two little contractile processes or arms, which become detached and move about like little worms, when they are termed "pseudo-filariæ," from their resemblance to free Nematoids. After a period of activity, the pseudo-filarian becomes quiescent, shortens its dimensions, develops a nucleus and nucleolus, and becomes an adult *Gregarina*.

In the gills of Fishes, and in the liver, muscles, &c., of certain Mammals, are found curious vesicular, often caudate bodies, which are known as "*Psorospermiæ*." These are in many respects like the pseudonavicellæ of Gregarines; but their true nature is uncertain.

As regards the habitat of different species of Gregarines in their adult state, *Gregarina blattarum* lives in the alimentary canal of the Cockroach, and *Gregarina gigantea* is found in the Lobster, reaching a length of half an inch. *Monocystis magna* inhabits the testes of the Earth-worm, and is an exceedingly common form; while *Monocystis lumbrici* lives in the skin of the same animal, the cysts showing themselves as white points below the transparent integument. *Monocystis capitata* is found, often in great numbers, attached to the hair in the human subject; and other species of the same genus are found in the muscles, or valves of the heart, or in the kidneys of man. Many other species are known, inhabiting the internal organs, body-cavity, or alimentary canal of various Invertebrate or Vertebrate animals. One or two forms have been found in decaying wood.

CHAPTER II.

RHIZOPODA.

(SARCODINA.)

GENERAL CHARACTERS OF THE RHIZOPODA.—The types which are grouped together under the name of Rhizopods may be defined as *Protozoa which are destitute of a mouth, and have the power of emitting pseudopodia.* The protoplasm is not provided with a definite external envelope or wall, and may be homogeneous, or may exhibit a division into a clear homogeneous outer layer ("ectoplasm" or "ectosarc"), and a more fluid and granular internal portion ("endoplasm" or "endosarc"). The characteristic "pseudopodia" are temporary processes of sarcode, sometimes thread-like, sometimes blunt or finger-shaped, which can be thrust out from various parts of the body, into the substance of which they again melt when retracted. They are used in locomotion and in obtaining food. A "nucleus" and "nucleolus" are often present in the protoplasm, and there may be one or more "contractile vesicles"; but in other cases all these structures may be wanting. In many instances the protoplasm has the power of secreting a skeleton of lime or flint; but in other cases no hard structures are developed.

Five principal types of structure are known in the *Rhizopoda*, and these constitute as many distinct orders, to which the names of *Monera*, *Amœbea*, *Foraminifera*, *Radiolaria*, and *Heliozoa* are given.

ORDER I. MONERA.—This name has been proposed by Haeckel for certain singular organisms which may provisionally be regarded as the lowest group of the *Rhizopoda*. They are very minute in size, and are distinguished by the fact that the body is composed of structureless sarcode, capable of emitting thread-like prolongations or pseudopodia, but destitute of either nucleus or contractile vesicle. The pseudopodia are mostly in the form of delicate filamentous processes of sarcode, which exhibit a circulation of minute molecules and granules in their interior and along their edges. Sometimes the pseudopodia may be simple, as in *Protamœba* (fig 15, *a*), or they may be ramified and anastomosing, as in *Protogenes* (fig. 1). The form of the body, though very mutable, may be simple; or the organism may form a kind of colony of protoplasmic masses united by their interlacing pseudopodia (as in *Myxo-*

dictyon). Sometimes the organism passes through a quiescent stage, alternating with a locomotive phase of existence. No hard covering or "test" is ever developed. Reproduction is mostly by fission, with or without precedent encystation (as in *Protomyxa*, fig. 15, *b* and *c*) and quiescence. All the *Monera* are

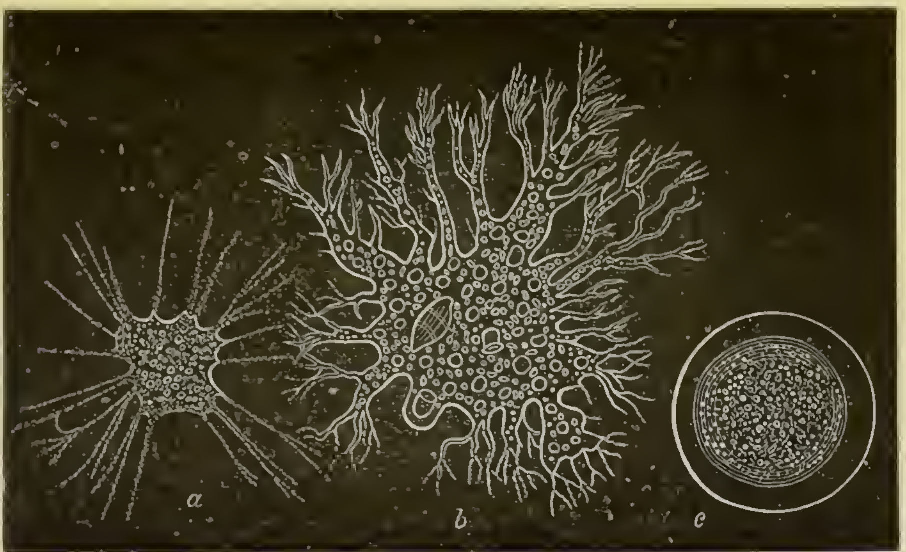


Fig. 15.—Morphology of *Monera*. *a Protamœba porrecta*; *b Protomyxa aurantiaca*; *c* The same in an encysted condition. Greatly magnified.

inhabitants of water, and they differ from forms like the *Amœba* in the fact that the body is a mere "cytode," or a "plasmodium"; the protoplasm being destitute of a nucleus, and not being differentiated into a distinct "ectosarc" and "endosarc."

ORDER II. AMŒBEA.—This order comprises those *Rhizopoda which are, with few exceptions, naked; have usually short, blunt, lobose pseudopodia, which do not anastomose with one another; and contain a "nucleus" (sometimes several such), together with one or more contractile vesicles.*

The *Amœbæ*, or Proteus-Animalcules, may be taken as types of this group, and a general description of one of these will sufficiently indicate the leading points of interest in the order. The *Amœbæ* are microscopic animalcules, which inhabit fresh water, or occasionally (*e.g.*, *Amœba terricola*) moist sand or earth. The body (fig. 16, B) is composed of gelatinous sarcode, which admits of a more or less distinct separation into two layers: an outer transparent layer, termed the "ectosarc" or "ectoplasm"; and an inner, more fluid and mobile, granular layer, called the "endosarc" or "endoplasm." The "ectosarc" is highly extensile and contractile, and is the layer

of which the pseudopodia are mainly composed; while the "endosarc" contains the "nucleus" (or nuclei) and the "contractile vesicle" (or vesicles), together with the temporary cavities known as "vacuoles."

It does not appear that the ectosarc is invested by any

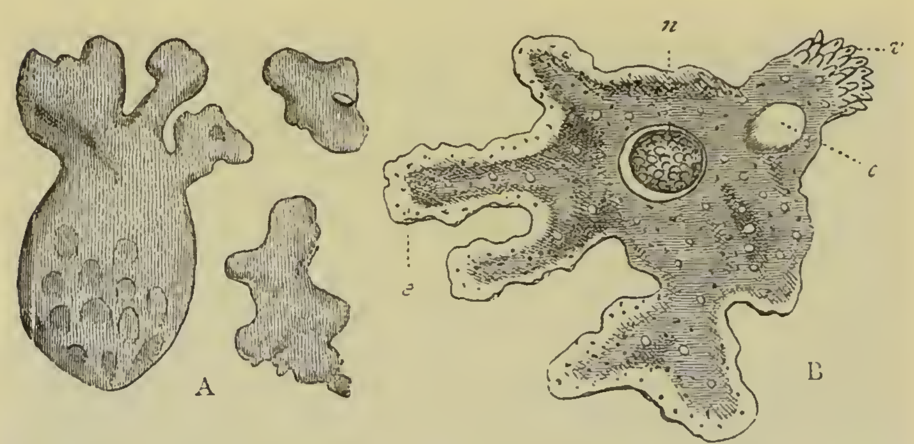


Fig. 16.—A, *Amœbæ* developed in organic infusions (after Beale), greatly enlarged. B, *Amœba princeps* (after Carter): *v* Villous region; *c* Contractile vesicle; *n* Nucleus; *e* Ectosarc.

proper outer membrane or "cuticle." There is also no proper oral aperture, and the food is merely taken into the interior of the body by a process of intussusception—any portion of the surface being chosen for this purpose, and acting as an extemporaneous mouth. Sometimes the ingestion of food takes place chiefly at the posterior end of the body. When the particle of food has been received into the body, the aperture by which it was admitted again closes up, and the discharge of solid excreta is effected in an exactly similar but reversed manner. In this case, however, the area of the general surface within which an anus may be extemporised, appears to be sometimes more restricted, and to comprise a portion only of the body ("villous region").

The "nucleus" (fig. 17, *n*) is an ovate, spheroidal, or discoidal body, consisting of an outer membrane enclosing fluid contents, and having a smaller body or "nucleolus" in its interior. In the typical *Amœbæ* there is usually only a single nucleus, but there may be two or more. Sometimes there are even many nuclei (as is also seen in such types as *Pelomyxa*); and in such cases the nuclei have been sometimes, erroneously, regarded as being connected with the function of reproduction.

The "contractile vesicles" are cavities within the endosarc (fig. 17, *c*), of which ordinarily only one is present in the same

individual, though there may be two or more. In position, the "contractile vesicle," or "pulsating vacuole," as it is often called, is usually placed towards the hinder end of the body,

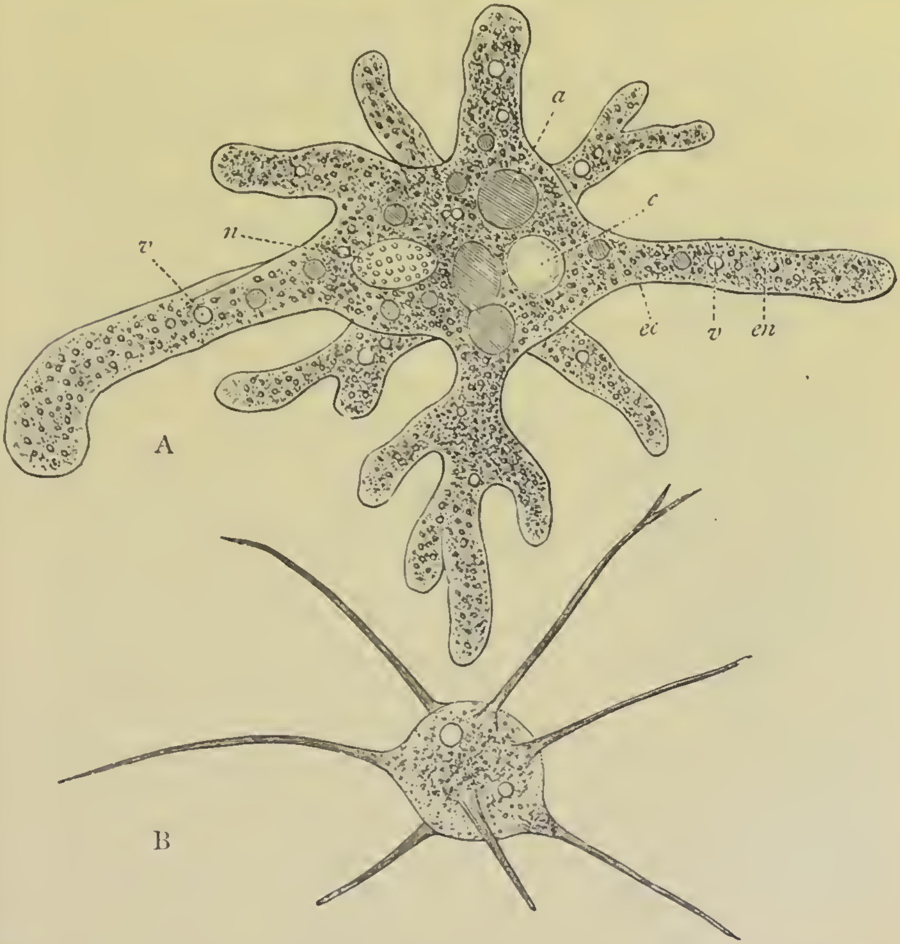


Fig. 17.—A, *Amœba proteus*, with the pseudopodia protruded, enlarged 200 diameters (after Leidy): *n* Nucleus; *c* Contractile vesicle; *v* One of the larger food-vacuoles; *en* The granular endosarc; *ec* The transparent ectosarc; *a* A cell of an Alga taken in as food (other cells of the same Alga are obliquely shaded). B, *Amœba* (*Dactylosphæra*) *radiosa*, enlarged 500 diameters (after Leidy). The body shows two large vacuoles, but no nucleus or contractile vesicle. The long and delicate pseudopodia are protruded.

as is also the nucleus. It consists of a spherical space or cavity in the sarcode, which becomes slowly dilated and filled with fluid, and then contracts, so as to drive its contents into the surrounding protoplasm. This action of alternate dilatation and contraction is rhythmically, though irregularly, performed. There is no connection, so far as certainly known, between the contractile vesicle and the exterior. Function-

ally, the contractile vesicle has been variously regarded as an excretory organ, or as a rudimentary circulatory organ. Most probably it is connected principally with excretion, and perhaps also with respiration (Leidy).

Besides the nucleus and contractile vesicle, the endosarc contains more or less numerous temporary spaces or "vacuoles." Some of these are simply cavities filled with fluid, which may be derived from the exterior, or may be the result of the process of digestion. Others, often called "food-vacuoles," are formed by the food-particles surrounded by a layer of fluid. In other, rarer cases, the vacuoles may contain some gas in their interior. Sometimes the vacuoles are comparatively small and few in number; in other cases, they may be very large and numerous, the sarcode thus assuming (as, for example, in *Pelomyxa*) a more or less frothy aspect. Sometimes the vacuoles may even be contractile, but they are always temporary structures, and are subject to the general movements of the endoplasm in which they are contained.

There are no traces of any organs of sense, or of a nervous system, or, indeed, of any other organs in addition to those already described. Locomotion is effected with moderate activity, but in an irregular manner, by means of the blunt, finger-shaped processes of sarcode, or pseudopodia, which can be protruded at will from any part of the body, and can be again retracted within it. The pseudopodia also serve as prehensile organs; but they do not interlace and form a network, nor do they exhibit any circulation of granules derived from the endosarc, as in many others of the *Rhizopoda*. In a few cases, the pseudopodia are comparatively long, slender, radiating processes. This is seen in *Amœba* (*Dactylosphæra*) *radiosa* (fig. 17, B); but in this instance the animal has the power of withdrawing its long pseudopodia and of throwing out short and blunt ones of the ordinary type. Of a somewhat different nature to the pseudopodia are the short, stiff, sarcodic processes which form a sort of tuft at the hinder end of the body in many *Amœbæ* (fig. 16, B).

The process of reproduction in the *Amœbæ* is only imperfectly known. The commonest method, however, by which new individuals are produced, is certainly by the simple fission or cleavage of the body into two parts. A phenomenon which has commonly been observed in the *Amœbæ* is that the animal under certain circumstances withdraws its pseudopodia and assumes a globular shape. The external layer of the protoplasm then thickens, and forms a kind of protective capsule to the endoplasm within. This condition of "encystation"

and quiescence has been supposed to be connected with the process of reproduction; but this supposition has not been satisfactorily established. It would rather seem to be the result of the supervention of unfavourable external conditions, and to be devoid of reproductive significance.

The remaining members of the *Amœbea* are constructed more or less closely after the type of the *Amœba* itself. In the nearly allied *Difflugia*, the sarcode forming the body of the animal is invested with a membranous envelope or "carapace," strengthened by grains of sand and other adventitious solid particles, and having a single aperture at one extremity, through which the pseudopodia are protruded (fig. 18). The animal generally creeps about head-downwards, so to speak; that is to say, with the closed end of the carapace elevated above the surface on which it is moving. *Difflugiæ* often exhibit the phenomenon known as "conjugation" or "zygosis." Under these circumstances, two *Difflugiæ* come in contact; the mouths of the two tests are brought together; the two animals flow backwards and forwards into each other's tests, with an apparently complete incorporation; and finally they separate again, and each retires to its own test. In *Arcella* there is a discoid or basin-shaped carapace, secreted by the animal itself, and likewise possessing but a single pseudopodial aperture, placed in this case on the flat surface of the body. One species of *Arcella* (viz., *A. arenaria*) is terrestrial in its habits.

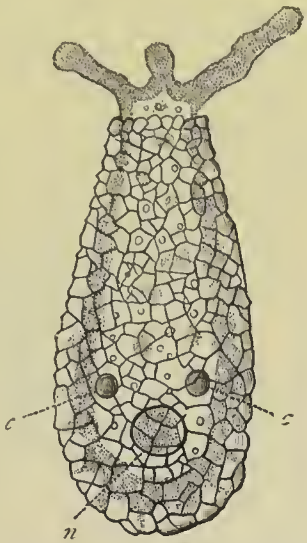


Fig. 18.—*Difflugia pyriformis*, greatly enlarged. (Altered slightly from Carter). The test is composed of angular grains of transparent quartz, within which is the transparent ectosarc, lined by the finely granular endosarc. *n* Nucleus; *c c* Contractile vesicles.

In *Pamphagus* the pseudopodia are protruded from one extremity of the body only, the rest of the surface forming a sort of thin investment which does not permit the protrusion of pseudopodia. *Cochliopodium* is like *Arcella*, but the test is quite flexible. *Pseudochlamys*, *Hyalosphenia*, *Quadrula*, &c., are other fresh-water Rhizopods more or less closely allied to *Arcella* and *Difflugia*, but often exhibiting interesting and remarkable modifications of structure.

The *Amœbea* may be divided into two sub-orders: 1. *Amœbina*, including those forms which have the body naked; and 2. *Arcellina*, comprising those in which the body is protected by a carapace. The latter are included by Hertwig and Lesser along with *Gromia* and the typical *Foraminifera* in a common group, to which they give the name of *Thalamophora*. The blunt and lobose character of the pseudopodia in the *Arcellina* would, however, appear to be a more important character than the possession of a test, and would assign to these forms a position close to *Amœba*.

CHAPTER III.

FORAMINIFERA.

(Reticularia.)

Order III. Foraminifera.—The *Foraminifera* may be defined as *Rhizopoda in which the body is protected by a shell or "test," composed of carbonate of lime, or of sand-grains cemented together, or, rarely, of chitine; there is no distinct separation of the sarcode of the body into ectosarc and endosarc, and a nucleus and contractile vesicle are present in at any rate some cases. The pseudopodia are long and filamentous, and interlace with one another to form a network.*

As regards the soft parts of the *Foraminifera*, the body is composed of extensile and contractile sarcode—usually reddish or yellowish in colour—which not only fills the interior of the shell, but generally invests its outer surface also with a thin film, from which the pseudopodia are emitted (fig. 19, *b*). The test, therefore, in this case, is not a true cuticular secretion, like that of the *Mollusca*, but it is truly immersed within the sarcode of the body. The sarcode is not differentiated into a distinct ectosarc and endosarc, and until recently was believed to be devoid of a nucleus and contractile vesicle, and, indeed, of any organs or specialised parts of any kind. Recent researches have, however, shown the presence of a nucleus and of contractile vesicles in, at any rate, some of the *Foraminifera;* and these structures are, therefore, probably generally present, though there are forms in which they seem to be altogether absent (*e.g.*, in *Lieberkühnia*). Even in the polythalamous forms there seems to be, as a rule, only one nucleus, so that the organism morphologically may be regarded as a single cell.

The pseudopodia in all the *Foraminifera* (fig. 20, *b*, *c*) are filamentous and protrusible to a great length, and they possess the singular property of uniting together in various directions so as to form a kind of network, like an "animated spider's web." (Hence the name *Reticulosa* applied to the order by Dr Carpenter.) This property, however, is not peculiar to the members of this order, but is seen also in *Actinophrys* and in the *Thalassicollida*, though to a less extent. Further, throughout the entire network formed by the inosculating pseudopodia there is a constant circulation of minute protoplasmic granules in different directions. As regards the phenomena

of this movement, Max Schultze observes that "as the passengers in a wide street swarm together, so do the granules in one of the broader threads make their way past each other, often-

Fig. 19.—Foraminifera. *a* The animal of *Nonionina*, after the shell has been removed by a weak acid; *b Gromia* (after Schultze), showing the shell surrounded by a network of filaments derived from the body-substance.

times stopping and hesitating, yet always pursuing a determinate direction, corresponding to the long axis of the thread. They frequently become stationary in the middle of their course, and then turn round; but the greater number pass to the extreme end of the pseudopodium, and then reverse the direction of their movement."

The *Foraminifera* are specially characterised by the possession of a "test" or external shell, which is usually composed of carbonate of lime, but is often made up of grains of sand or other adventitious solid particles cemented together by animal matter, or which, as in *Gromia*, may be simply chitin-

ous. The test may be composed of an aggregation of chambers or "loculi" (fig. 20, *c*), or of a single chamber only, and its walls are usually pierced by numerous pores or "foramina" through which the pseudopodia are protruded; the place of these being in other forms supplied by the large size of the

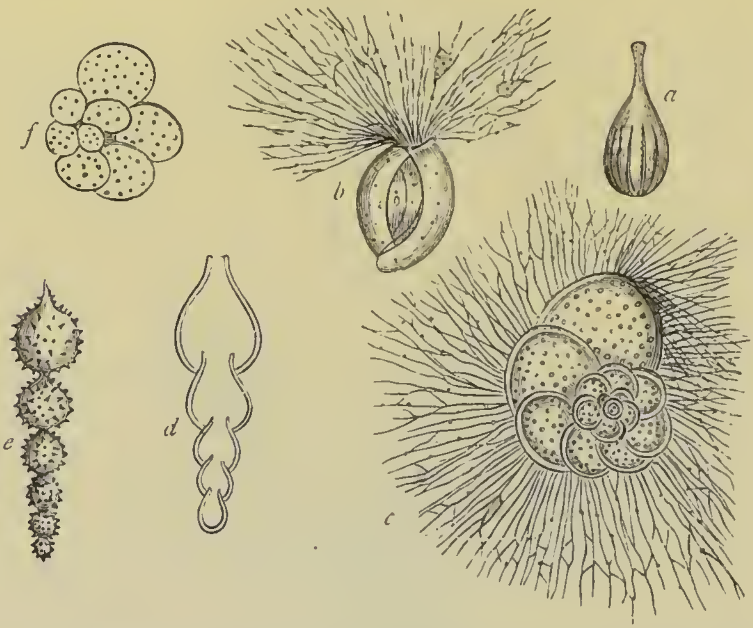


Fig. 20.—Morphology of Foraminifera. *a Lagena vulgaris*, a monothalamous Foraminifer; *b Miliola* (after Schultze), showing the pseudopodia protruded from the oral aperture of the shell; *c Discorbina* (after Schultze), showing the nautiloid shell with the foramina in the shell-wall giving exit to pseudopodia; *d* Section of *Nodosaria* (after Carpenter); *e Nodosaria hispida*; *f Globigerina bulloides*.

terminal, or "*oral*," aperture of the shell (fig. 20, *b*), the walls themselves being imperforate.

The least highly developed form of shell in the *Foraminifera* is that which consists merely of a thinner or thicker chitinous envelope, as is seen in *Gromia* (fig. 19, *b*). This is in *Lieberkühnia* reduced to little more than a kind of moderately resisting cuticle.

An advance upon the chitinous shell is that presented by the so-called "arenaceous" *Foraminifera* (fig. 21), which are among the largest of the living types, the test being sometimes half an inch or more in length. In some cases the "arenaceous" test is nothing more than a chitinous envelope, protected by a layer of mud, or having sand-grains more or less largely embedded in its substance (H. B. Brady). Typically, however, the test of the arenaceous *Foraminifera* consists of sand-grains or other foreign particles united together by a variable

amount of a cementing material, this latter consisting principally of peroxide of iron and carbonate of lime (H. B. Brady).

The great majority of the *Foraminifera* possess a shell com-

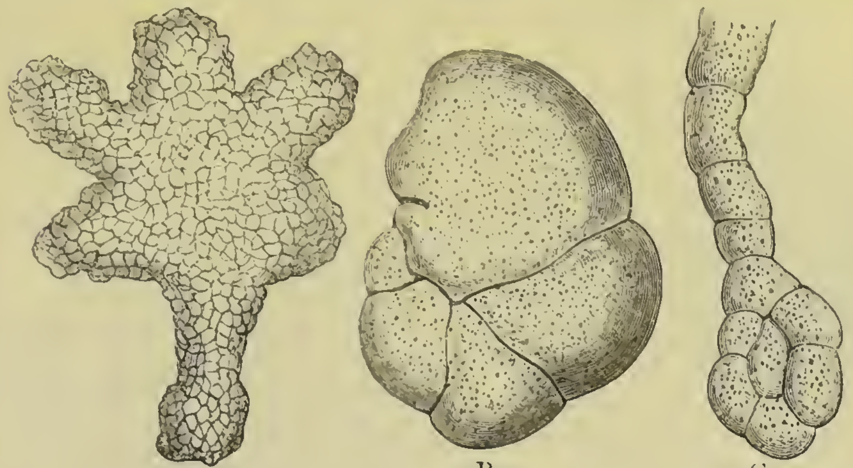


Fig. 21.—Shells of Arenaceous Foraminifera. A, Test of *Astrorhiza*, greatly enlarged; B, Test of *Trochammina ringens*, enlarged thirty times; C, Test of *Trochammina lituiformis*, enlarged eighteen times. (After Carpenter and Brady.)

posed of carbonate of lime, with or without variable quantities of other constituents. Two chief varieties of these calcareous shells are known, termed respectively the "porcellanous" and the "hyaline" or "vitreous" types. In the so-called "porcellanous" shells (as in *Miliola*, fig. 20, *b*), the test is quite homogeneous in its composition, opaque-white when seen by reflected light, and having its walls not perforated by pseudopodial apertures. Normally the shell is calcareous, but it may be incrusted by sand-grains, or it may even be to a larger or smaller extent composed of silica, as Mr Henry Brady has shown to be sometimes the case in certain of the *Miliolidæ*. The so-called "hyaline" or "vitreous" shell is also calcareous in its composition, but it is transparent and glassy in texture, and its walls are perforated by numerous pseudopodial apertures.

As has just been mentioned, the test in many *Foraminifera* has its walls perforated by numerous tubules, which open on the surface, and permit of the exit of the pseudopodia, whereas in others the shell-wall is without these pseudopodial foramina. This has been used as a character to divide the entire group of the *Foraminifera* into the two sections of the *Perforata* and *Imperforata;* the former including the hyaline or vitreous types, while in the latter are comprised the "porcellanous," "arenaceous," and "chitinous" types. It has been shown, however,

that this division is not strictly natural, since various arenaceous types possess a test which is more or less extensively porous.

It would appear, therefore, that the composition of the shell is liable to variation, in accordance with the nature of the materials obtainable at any particular station by the organism, so that too great stress cannot be laid upon this character in classification. As a rule, the arenaceous test is imperforate, and the pseudopodia are emitted by the terminal aperture of the shell; but cases are not unknown in which the walls are porous. Finally, there is a group of forms in which the test (as in *Gromia*) is composed simply of chitine.

In some of the *Foraminifera*, hence called "simple" or "unilocular" (*Monothalamia*), the shell consists of a single chamber, and the animal is, in fact, nothing more than a little mass of sarcode enveloped in a chitinous or calcareous covering. *Orbulina* (fig. 22, *a*), or *Lagena* (fig. 20, *a*) with its beautiful flask-shaped shell, may be taken as types of this division. Another well-known unilocular form is *Entosolenia*, which is like *Lagena* in shape, but has the tubular neck reversed, so as to be inserted into the interior of the test. In the more complex *Foraminifera*, the sarcode of the body undergoes a subdivision into partially separated segments, produced by constrictions in the growing protoplasm, and each of these segments becomes more or less completely divided off from its neighbours, or enclosed by a wall of shell. In these "multilocular" or "polythalamous" *Foraminifera*, therefore, the shell ultimately comes to consist of a series of chambers, separated by partitions of the test, and filled with sarcode (fig. 22, *b-f*). The partitions, however, or "septa," between the different chambers, are perforated by one or more apertures, through which pass connecting-bands, or "stolons," of sarcode; so that the sarcode occupying the different chambers is united into a continuous and organic whole. Each segment may give out its own pseudopodia through perforations in its investing wall (fig. 20, *c*), or the pseudopodia may be simply emitted from the mouth of the shell by the last segment only (fig. 20, *b*). In any case the direction in which the segments are developed is governed by a determinate law, and differs in different species, the form ultimately assumed by the shell depending wholly upon this. The forms, however, assumed by the shells of *Foraminifera* are extremely variable, and it would be impossible to notice even the chief types in this place. There are, however, two or three important variations which may be noticed. If the segments of the protoplasm are produced in a

linear series, so as to form a shell composed of numerous chambers arranged in a straight line, we get such a type as *Nodosaria* (fig. 20, *e*). If the shell consists of a double alternate parallel series of chambers, we have such a type as *Textularia* (fig. 22, *c*). When the new chambers are added in a

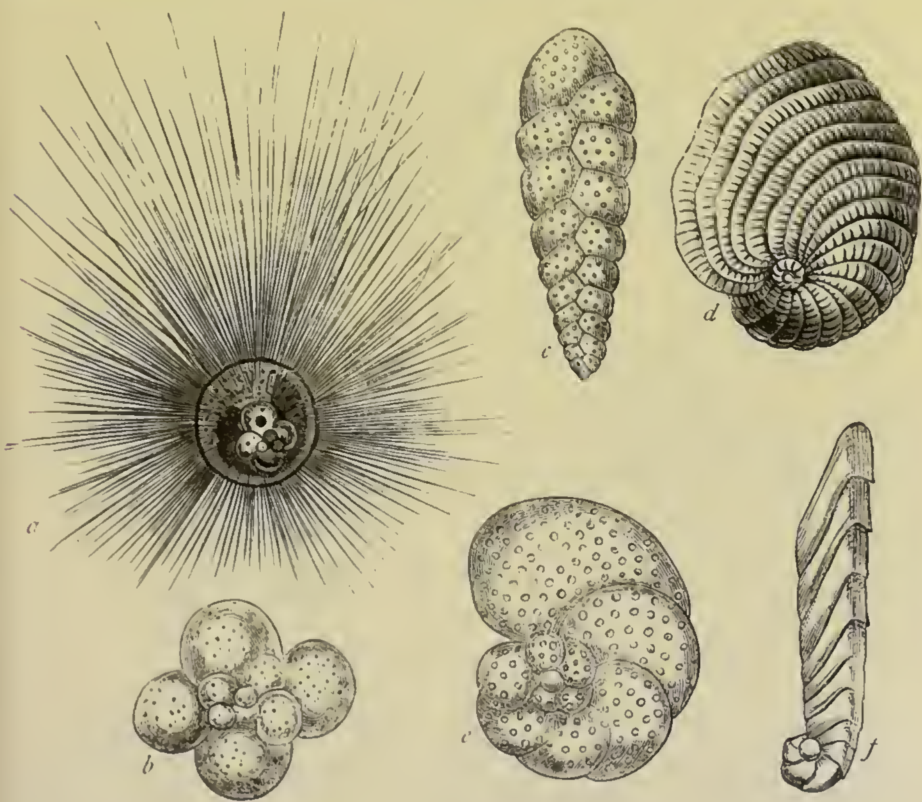


Fig. 22.—Shells of *Foraminifera*. *a*, *Orbulina universa*, in its perfect condition, showing the tubular spines which radiate from the surface of the shell; *b*, *Globigerina bulloides*, in its ordinary condition, the thin hollow spines which are attached to the shell when perfect having been broken off; *c*, *Textularia variabilis*; *d*, *Peneroplis planatus*; *e*, *Rotalia concamerata*; *f*, *Cristellaria subarcuatula*. (Fig. *a* is after Wyville Thomson; the others are after Williamson. All the figures are greatly enlarged.)

spiral direction, each being a little larger than the one which preceded it, and the coils of the spiral lying in the same plane, we get such a form as *Discorbina* (fig. 20, *c*), or *Robulina*. These are the so-called "nautiloid" *Foraminifera*, from the resemblance of the shell, in figure, to that of the Pearly Nautilus. From this resemblance the nautiloid *Foraminifera* were originally placed in the same class as the Nautilus (*Cephalopoda*), but their true position was shown by the examination of their soft parts. In the typical nautiloid shell the convolutions of the spiral all lie in one plane; but in other

cases, as in *Rotalia* (fig. 22, *e*) the shell becomes turreted or top-shaped, in consequence of the coils of the spiral passing obliquely round a central axis. In other cases, as in *Tinoporus*, the chambers are arranged in an irregular or "acervuline" manner.

In certain of the polythalamous *Foraminifera*, the successive chambers are so produced that the septum between any two of them is formed solely by the anterior wall of the older chamber, which thus constitutes the posterior wall of the newer one (fig. 20, *e*). In the highest types of the compound *Foraminifera*, however, each segment is provided with its own proper wall of shell, each segment, as it is produced, forming for itself a posterior wall which applies itself to the anterior wall of the preceding segment, so that each septum ("septal plane") is composed of *two* lamellæ, as seen in fig. 23, A (Carpenter). Moreover, "in the higher types of the

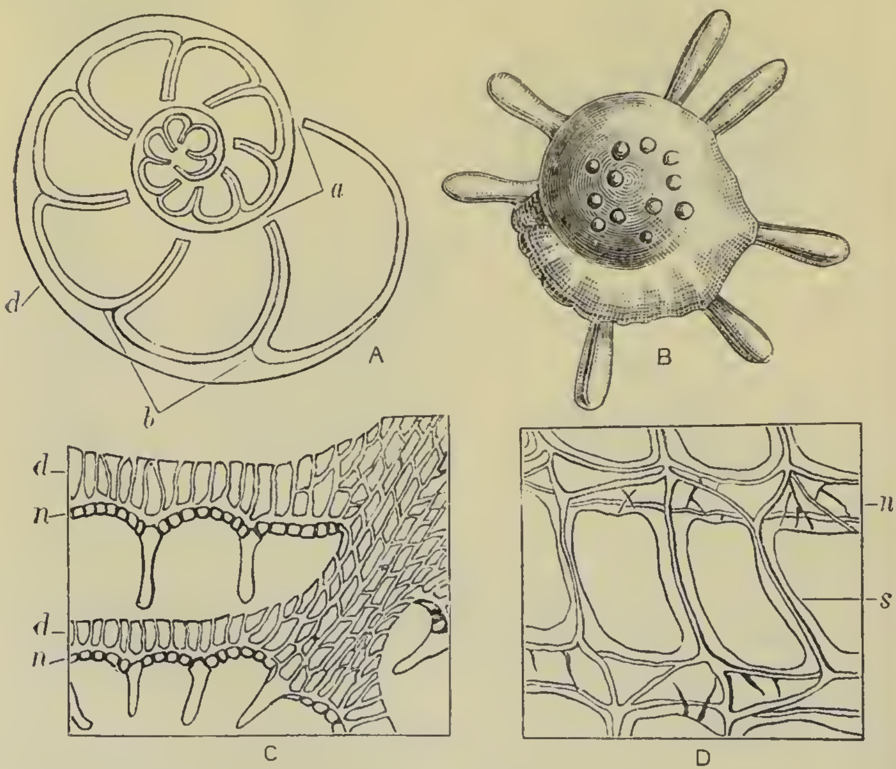


Fig. 23.—A, Diagram of one of the higher forms of the vitreous *Foraminifera*, showing the double nature of the septa (*b*), the stolon-passages between successive chambers (*a*), and the supplemental skeleton (*d*); B, Test of *Calcarina Spengleri*, magnified twelve diameters, showing the spines formed by the supplemental skeleton; C, Part of a section of the test of *Calcarina*, magnified fifty diameters, showing the tubulated "proper walls" of the chambers (*n*), and the canal-system of the intermediate skeleton (*d*); D, Part of the test of *Nummulina lævigata*, highly magnified, showing the canal-system of the septa (*s*), and marginal cord (*n*). (After Carpenter.)

hyaline or vitreous series we frequently meet with an 'intermediate' or 'supplemental' skeleton, formed by a secondary or exogenous deposit upon the outer walls of the chambers, by which they receive a great accession

of strength. This deposit not only fills up what would otherwise be superficial hollows at the junctions of the chambers (fig. 23, A, *d*), or (as in *Polystomella*) at the umbilical depression, but often forms a layer of considerable thickness over the whole surface, thus separating each whorl from that which encloses it ; and it is sometimes prolonged into outgrowths that give a very peculiar variety to the ordinary contour, as in some varieties of *Rotalia* and *Polystomella*, but most characteristically in *Calcarina* (fig. 23, B). This intermediate or supplemental skeleton, wherever developed to any considerable extent, is traversed by a set of 'canals,' which are usually arranged upon a systematic plan, and are sometimes distributed with considerable minuteness" (Carpenter). The canals of this system are doubtless filled in the living state by prolongations of the sarcode, which serve to keep up the vitality of the intermediate skeleton. This intermediate skeleton, with its canal-system, is largely developed in many of the highest and largest of the types of the Hyaline *Foraminifera* (such as *Nummulina*).

A few words may be added here with regard to those *Foraminifera* which have a chitinous test, or in which the protoplasm is protected by a sort of pseudo-test (as in *Diaphoropodon*) formed of adventitious particles. These forms have been included in a single group of which *Gromia* is the type, and to which the name of *Gromidæ* has been applied. The test is always one-chambered, and usually has an opening or "mouth" at one end only, rarely at both ends. A nucleus and contractile vesicles may be present or wanting; and the pseudopodia are long and filamentous, and more or less reticulated. Of these simple types, *Gromia* (fig. 19, *b*) is represented by both marine and fresh-water species, one species being known to inhabit moss. The test is a chitinous capsule, from a terminal aperture in which the protoplasm gains the exterior. *Lieberkühnia* is like *Gromia*, but the test is exceedingly delicate, and the pseudopodia are given off from a kind of common stalk, instead of from the whole surface of the body. *Microgromia* (fig. 24) resembles *Gromia* in structure, but forms loose colonies by the root-like union of the pseudopodia of a number of individuals. It lives in fresh water, and reproduces itself by giving exit to amœboid masses of protoplasm, each of which develops two flagella, thus constituting free locomotive "swarm-spores." *Euglypha* and *Diplophrys* are other forms allied to *Gromia*, the former having an inflexible and sculptured test, while the latter has two oppositely-placed apertures in the shell, in place of a single terminal opening.

Classification of the Foraminifera.—The earlier classifications of the *Foraminifera* were based chiefly upon the form of the shell, and were purely artificial. More recent classifications have usually been based upon the "perforate" or "imperforate" character of the shell as a primary dis-

tinction. By Mr Henry B. Brady, the minute structure of the test has been abandoned as an exclusive basis for the subdivision of the *Foraminifera*,

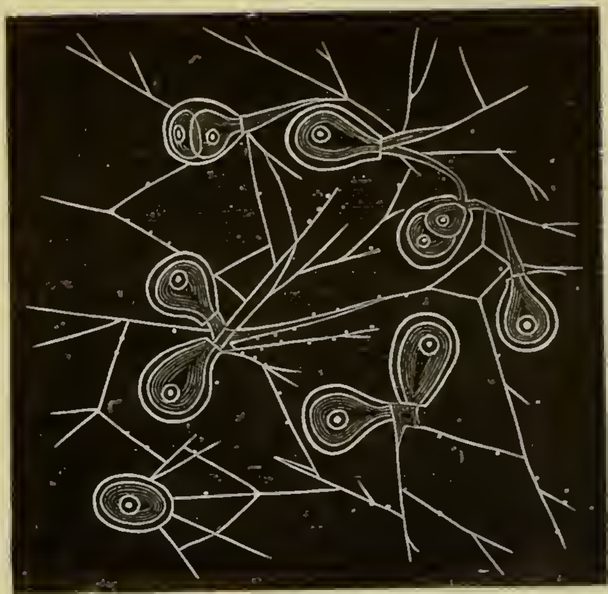


Fig. 24.—A colony of *Microgromia socialis*, showing the different members of the colony united by their branching pseudopodia. Greatly enlarged. (After Hertwig.)

and it will be sufficient to subjoin here a table of the families into which the order is divided by this eminent authority:—

ORDER FORAMINIFERA (RETICULARIA).

Family 1. GROMIDÆ.—Test chitinous; smooth or encrusted with foreign bodies; with a pseudopodial aperture at one or both extremities. *Ex.—Gromia*, *Microgromia*, *Lieberkühnia*.

Family 2. MILIOLIDÆ.—Test imperforate; normally calcareous and porcellanous, sometimes encrusted with sand, or, under certain conditions, chitinous or siliceous. *Ex.—Biloculina*, *Peneroplis* (fig. 22, *d*), *Orbitolites*.

Family 3. ASTRORHIZIDÆ. —Test composed of sand-grains or other foreign bodies, usually more or less united into a coherent test by a cementing material. Usually the test is monothalamous, often branched or radiate, sometimes partially subdivided, but seldom or never truly septate. *Ex.—Astrorhiza* (fig. 21, A), *Rhabdammina*, *Saccammina*.

Family 4. LITUOLIDÆ.—Test arenaceous, usually regular in contour; septation of the polythalamous forms often imperfect; chambers frequently labyrinthic. *Ex.—Lituola*, *Trochammina* (fig. 21, B and C), *Endothyra*.

Family 5. TEXTULARIDÆ.—Tests of the larger species arenaceous, with or without a perforate calcareous basis; smaller forms hyaline and perforated. Chambers arranged in two or more alternating series, or spiral, or confused. *Ex.—Textularia*, *Valvulina*.

Family 6. CHILOSTOMELLIDÆ.—Test calcareous, perforate, polythalamous. Segments following each other from the same end of the long axis, or alternately at the two ends, or in cycles of three; more or less embracing. Aperture a curved slit at the end or margin of the final segment. *Ex.—Chilostomella*.

Family 7. LAGENIDÆ. —Test calcareous, finely perforated; either mono-

thalamous, or consisting of a number of chambers joined in a straight, curved, spiral, alternating, or (rarely) branched series. Aperture simple or radiate, terminal. No interseptal skeleton nor canal-system. *Ex.—Lagena*, *Nodosaria*, *Cristellaria*.

Family 8. GLOBIGERINIDÆ.—Test free, calcareous, perforate; chambers few, inflated, arranged spirally. Aperture single or multiple, conspicuous. No supplementary skeleton nor canal-system. *Ex.—Globigerina*, *Orbulina*.

Family 9. ROTALIDÆ.—Test calcareous, perforate; free or adherent. Typically spiral and "rotaliform"—*i.e.*, coiled in such a manner that the whole of the segments are visible on the upper surface, those of the last convolution only on the inferior or apertural side. *Ex.—Rotalia*, *Discorbina*.

Family 10. NUMMULINIDÆ.—Test calcareous and finely tubulated; typically free, polythalamous, and symmetrically spiral. Often a "supplemental skeleton" and canal-system. *Ex.—Nummulina*, *Polystomella*, *Fusulina*, *Nonionina*.

DISTRIBUTION OF THE FORAMINIFERA IN SPACE.—A comparatively small number of the *Foraminifera*, including such types as *Gromia* (some species), *Lieberkühnia*, *Euglypha*, &c., are fresh-water in habit; but by far the larger number of forms live in the sea. One species of *Gromia* is terrestrial. As regards the marine forms, many species abound in shallow water, and may be obtained by dredging, by searching in the shelly sand of the sea-shore, or by examining submarine bodies of all kinds which may be thrown up on shore during storms.

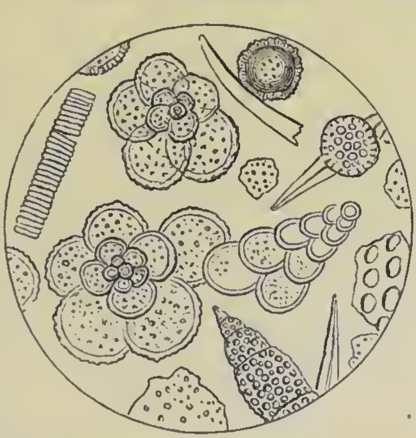


Fig. 25.—Organisms in the Atlantic ooze, chiefly *Foraminifera* (*Globigerina* and *Textularia*), with *Polycystina*, and Sponge-spicules; highly magnified. (Original.)

A small number of types, belonging, according to Mr Henry Brady, to eight or nine genera, are pelagic in their habits, and "pass their existence, either in part or entirely, at the surface of the ocean or in mid-water." By far the largest number of types, however, are destitute of swimming or floating powers, and live on the bottom of the sea. Though only a few genera have pelagic representatives, these few are of great importance, owing to the extraordinary profusion in which they occur individually. The principal pelagic genus is *Globigerina* (fig. 22, *b*), most of the species of which live in the open sea, though one species seems to live always at the bottom. The shells of the pelagic *Foraminifera*, after the death of the animal, fall to the bottom of the sea,

where they accumulate to form (along with the shells of the species which live habitually at the bottom) great deposits of "Foraminiferal mud." Thus, the bottom of the deep sea is covered over vast areas with a calcareous mud or "ooze" formed chiefly of the shells of *Foraminifera*, the genus *Globigerina* (fig. 25) playing the principal part in the formation of these deposits. The deep-sea dredgings of late years have further brought to light a great number of forms of "arenaceous" *Foraminifera* of the most varied and interesting nature.

Distribution of Foraminifera in Time.—Remains of *Foraminifera* are found abundantly in all the great stratified formations except the very oldest. Leaving out of sight the problematical body to which the name of *Eozoön* has been applied, the earliest remains of *Foraminifera* occur in the Ordovician rocks. In the later Palæozoic rocks extensive beds of limestone are often largely, or almost wholly, made up of the tests of *Foraminifera*. Examples of these "Foraminiferal limestones" are the "*Fusulina* limestones" of the Carboniferous formations of Russia, Armenia, &c.; the "*Endothyra* limestones" of the same formation in North America; and the "*Saccammina* limestones" of the Carboniferous series of Britain. The genus *Saccammina* is particularly interesting, as it not only occurs in rocks as old as the Ordovician, but Sars has found vast numbers of a living species of the same in the North Sea. In the Secondary rocks, *Foraminifera* occur in great abundance. The thick and widely-spread formation of the White Chalk, in particular, is largely composed of the shells of *Globigerina* and of other *Foraminifera*, and it may therefore be regarded as an ancient representative of the "Foraminiferal Ooze" of modern oceans. Lastly, in the Tertiary rocks, the *Foraminifera* attain their maximum of develop-

1 2 3

Fig. 26.—*Nummulina lævigata*. Eocene.

ment, both as regards the size and the number of the forms which characterise them. The period of the Middle Eocene is especially distinguished by a very widely-spread and easily-

recognised rock known as the Nummulitic Limestone, so called from the abundance in it of a large coin-shaped *Foraminifer* termed the *Nummulite* (fig. 26). The Nummulitic Limestone stretches from the west of Europe to the frontiers of China; but in some cases, in place of *Nummulina* proper, it contains the remains of a different, but similarly-shaped, form termed *Orbitoides*.

CHAPTER IV.

RADIOLARIA AND HELIOZOA.

ORDER IV. RADIOLARIA.—The *Radiolaria* may be defined as *Rhizopods in which the sarcode-body consists of a central protoplasmic mass (or of several such), enclosed in a more or less porous, membranous, or chitinous capsule, which in turn is surrounded by an envelope of sarcode. The pseudopodia have the form of slender radiating filaments, which rarely anastomose with one another. Usually, the protoplasmic body secretes a radially-disposed siliceous skeleton. No contractile vesicle is present.*

The protoplasm of the body of a Radiolarian consists typically of a central and a peripheral portion, of which the former is enclosed in a porous, membranous, or chitinous capsule, while the latter is surrounded by a gelatinous investment. The extra-capsular sarcode is often brightly coloured, and is usually more or less largely vacuolated. From its outer surface are given out the long, filamentous, radiately-disposed pseudopodia (fig. 27), and within it are contained, as a rule, more or less numerous nucleated cells, which have yellow protoplasmic contents along with starch granules, and which have been commonly spoken of as "yellow cells." These singular structures are known to be really parasitic *Algæ*. The intra-capsular sarcode contains a single nucleus or several small nuclei, but there is no contractile vesicle. Skeletal structures, in the form of spicular, radiating spines, or fenestrated shells, may be developed in either the extra-capsular or the intra-capsular sarcode, or in both. These skeletal structures may be wanting; but, when present, they are almost always siliceous, rarely horny, never calcareous. The animal is usually simple, varying in size from $\frac{1}{600}$ to $\frac{1}{20}$ inch, or rarely more, but in other cases (*Collozoum*) colonies are formed, which may reach two inches in diameter.

Reproduction is often by fission; but in other cases the intra-capsular sarcode breaks up into minute germs or zoöspores, each of which possess a nucleus and a flagellum.

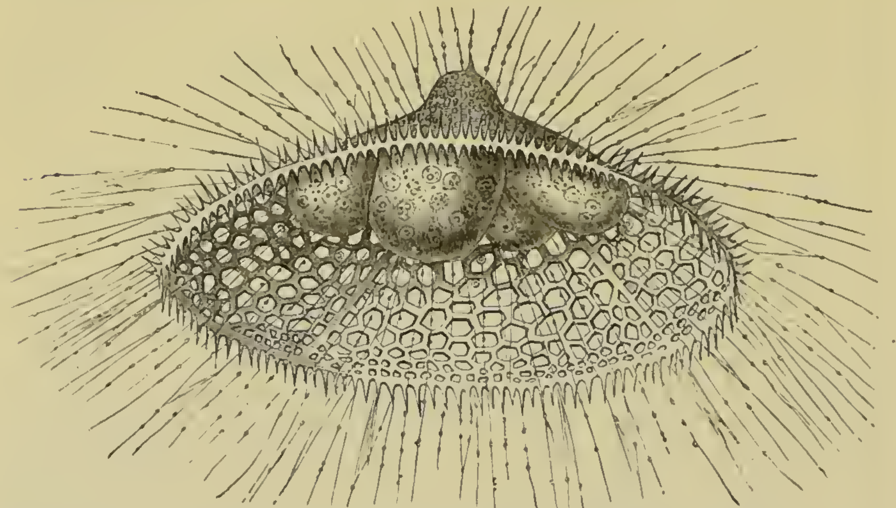


Fig. 27. *Eucecryphalus Schultzei*, with the pseudopodia extended, showing the perforated siliceous test and the lobed protoplasmic body. After Kölliker. (The author is indebted to the kindness of Professor Mivart for the use of this engraving.)

The following are the more important groups of the *Radiolaria*:—

I. Family Acanthometrina.—The *Acanthometræ* (fig. 28, *a*) are all minute, and are found floating near the surface in the

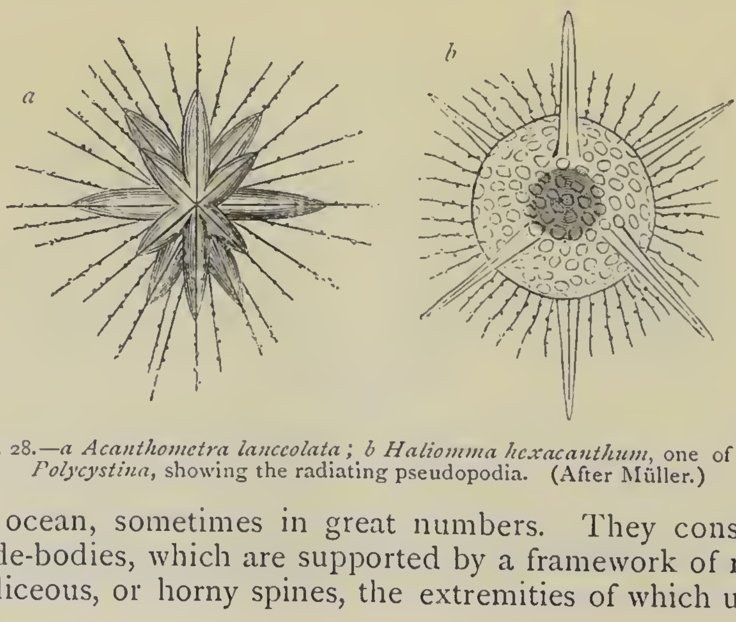


Fig. 28.—*a Acanthometra lanceolata*; *b Haliomma hexacanthum*, one of the *Polycystina*, showing the radiating pseudopodia. (After Müller.)

open ocean, sometimes in great numbers. They consist of sarcode-bodies, which are supported by a framework of radiating siliceous, or horny spines, the extremities of which usually

project considerably beyond the body. The siliceous spines are hollow, being grooved at the base by a gutter, which is continued further up the spine by a canal terminating at the apex of the spine by a distinct aperture. The spines, in consequence of this structure, are able to serve for the transmission of the pseudopodia, which gain the exterior by running through the canals and escaping at their apices. Many of the pseudopodia, however, do not occupy the canals of the spines.

II. Fam. Polycystina.—The members of this family possess a body of sarcode, which is enclosed in a foraminated siliceous shell, which is often furnished with spine-like processes, and is usually of great beauty (figs. 27, 28, 29). The sarcodic substance of the body is olive-brown in colour, with yellow globules, and often does not entirely fill the shell. The pseudopodia are emitted through the foramina in the test, and are long, ray-like filaments, which display a slow movement of granules along their borders. A nucleus has been stated to be wanting.

The *Polycystina* are all microscopic, and are all inhabitants of the sea, having a very wide distribution. They likewise extend to great depths; and one of the numerous facts of in-

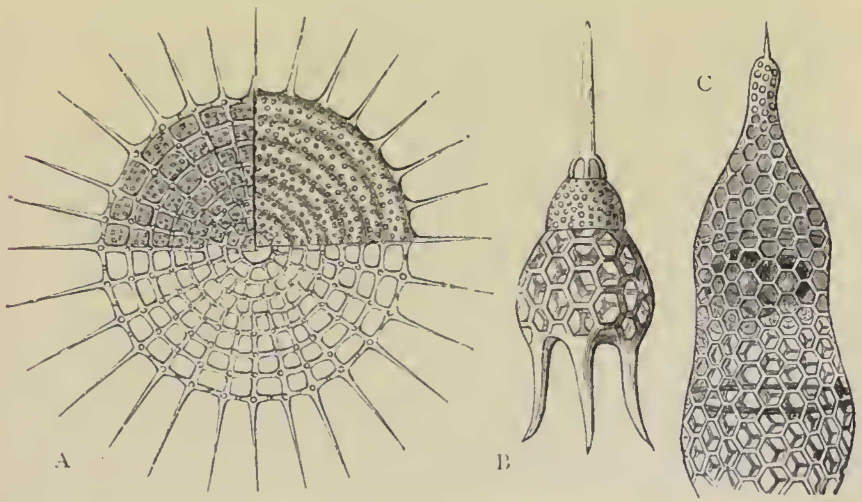


Fig. 29.—Skeletons of *Polycystina*. A, *Stylodictya multispina*; B, *Podocyrtis Schomburgii*; C, *Eucyrtidium lagena*. (After Haeckel.)

terest brought to light by the researches of the Challenger Expedition, under Sir Wyville Thomson, has been that large areas of the sea-bottom, up to the enormous depth of 4500 fathoms, are formed by an "ooze" composed of the siliceous

cases of *Polycystina* and other Radiolarians. Similar deposits of Tertiary age are known as occurring in the crust of the earth in various regions. One of the best known of these is the "Barbadoes Earth," which is almost wholly composed of the delicate flinty shells of the *Polycystina*. The remains of *Polycystina* have also now been detected in rocks as old as the Jurassic formation.

III. Fam. Collozoa.—In this family the organism is usually compound, though occasionally simple. A skeleton may be wholly wanting (as in the composite *Collozoum*), or may exist in the form of spicules or of a foraminated shell. The simple types always possess a mere spicular skeleton, and the same is true in such forms as *Sphærozoum* (fig. 30, *b*). On the other

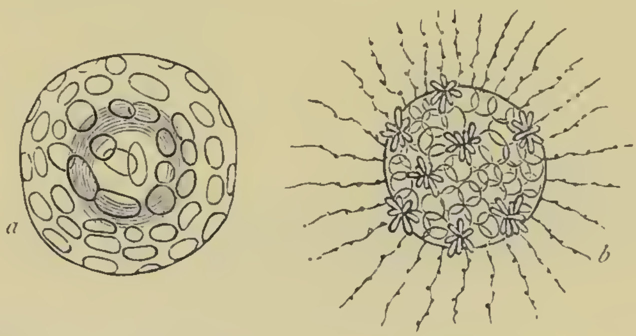


Fig. 30.—Morphology of Radiolaria. *a* Siliceous fenestrated test of *Collosphæra Huxleyi*; *b Sphærozoum morum*, showing numerous capsules, compound groups of spicules, and radiating pseudopodia.

hand, in such forms as *Collosphæra* (fig. 30, *a*) there is a spheroidal fenestrated test, the skeleton thus approximating in character to that of the *Polycystina*. The members of this family sometimes attain a considerable size, and are found floating near the surface in most seas.

IV. Fam. Thalassicollida.—This family, as now restricted, comprises floating marine organisms, which are in many respects closely allied to the preceding, but in which the intra-capsular sarcode contains a complex nucleus. The skeleton may be wanting (as in *Thalassicolla* and *Thalassolampe*), or it may be present in the form of spicules or spines developed in the extra-capsular sarcode.

Order V. Heliozoa.—The *Heliozoa* may be defined as *Rhizopoda, which possess a contractile vesicle, and are devoid of a central capsule. The body is naked, or is provided with skeletal structures of a variable nature, but sometimes siliceous. The pseudopodia stand out like rays, but may anastomose with one another.*

In their radiant *pseudopodia* and in the occasional presence of siliceous spicules, the *Heliozoa* are allied to the typical Radiolarians; but in the absence of a central capsule and the presence of a contractile vesicle, they approximate to the *Amœbea.* They must therefore be regarded as an inosculating group, related on the one hand to the *Amœbea,* and on the other to the *Radiolaria.*

All the *Heliozoa* are inhabitants of fresh water, and we may select as a type the common "Sun-animalcule" (*Actinophrys sol*), in which no hard structures are developed. In this animalcule (fig. 31), the body consists of a spherical mass

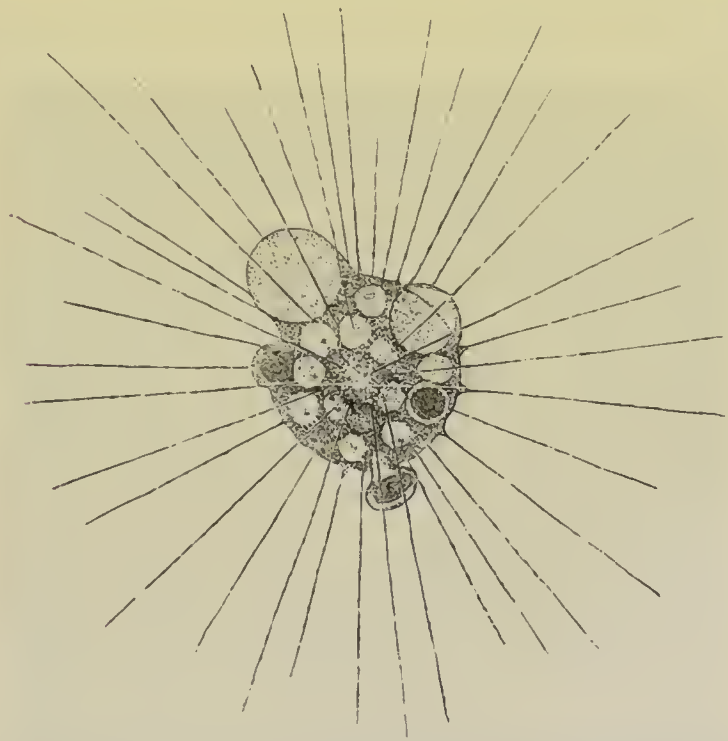


Fig. 31.—*Actinophrys sol,* magnified 500 diameters. (After Leidy). The large projecting sphere on one side is the contractile vesicle, while the smaller light spaces are vacuoles; the shaded spherules belong to *Algæ* taken as food.

of sarcode, about $\frac{1}{1300}$ of an inch in diameter, and usually covered with long radiating, filamentous pseudopodia, which are much less mobile than in the case of the *Amœba.* The division of the substance of the body into ectosarc and endosarc is tolerably evident, and the latter contains numerous granules and vacuoles. The pseudopodia are derived from the ectosarc alone, the endosarc not passing into them, and

they exhibit a circulation of granules along their edges, though this is not nearly so marked a feature as in the case of the *Foraminifera*. A nucleus and contractile vesicle are also present, the former being of very large size, while the latter projects beyond the general surface. Several individuals often become fused together, with a complete amalgamation of their bodies, the nuclei alone remaining distinct; and the individuals thus united may become again separate.

Actinophrys occurs in both fresh and salt water. *Actinosphærium* is in many respects like *Actinophrys*, but each of the pseudopodia is supported upon a strong albuminous spine; and the sarcode of the body is vesicular or "alveolar," while numerous nuclei exist in the central sarcode. In *Heterophrys* (fig. 32), there is a globular body, the ectosarc of which is sur-

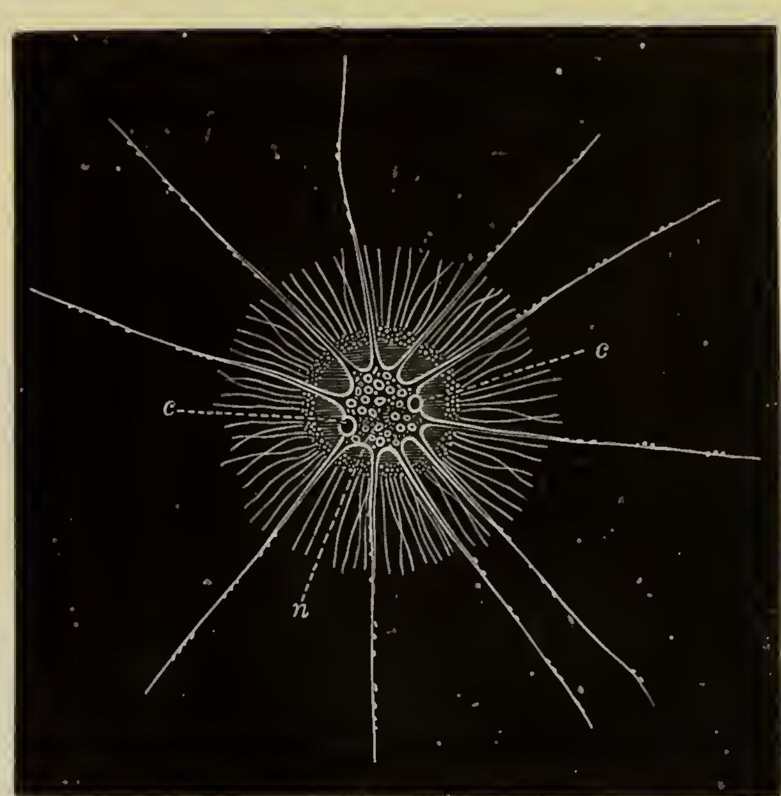


Fig. 32.—*Heterophrys spinifera*, one of the *Heliozoa*, greatly enlarged. (After Hertwig and Lesser.) *c c* Contractile vesicles.

rounded by a kind of external investment or excretion, which appears to be of a protoplasmic nature, but takes no part in the production of the pseudopodia. The latter are long, granular, and unbranched, and amongst them are long spine-like processes of firm sarcode, which have been regarded as of a chit-

inous nature. *Acanthocystis* is, like the preceding, a fresh-water form, but it possesses long radiating siliceous spines; while *Clathrulina* has the body enclosed in a regular fenestrated siliceous test, which is supported upon a siliceous peduncle.

CHAPTER V.

INFUSORIA.

THE name of *Infusoria* has been given to the members of this class of the *Protozoa* because of their common occurrence in "organic infusions"—that is, in water in which some organic substance has been boiled. In point of fact, the Infusorian animalcules are found in all collections of fresh or salt water, provided only that organic matter is also present. Very many of them have the power of surviving desiccation, under which circumstances they pass into a dormant state. In this semi-torpid encysted condition, or as spores or germs, they may be taken up into the atmosphere, forming one of the elements of atmospheric dust, and being thus capable of transportation to long distances. "Essentially dependent on a liquid medium for the exhibition of their vital functions, there is practically—the simple conditions of air and moisture being granted them—no limit to the area of their distribution" (Saville Kent). With their almost universal distribution, their very minute size, and their power of remaining for long periods in a condition of suspended vitality when dried up, it is no wonder that they should appear, as it were, "spontaneously" in organic fluids when these are placed under suitable conditions. On the other hand, owing to the soft nature of their bodies, the history of the Infusorian animalcules in past time is almost a complete blank. The so-called "fossil Infusoria" of the older writers belong to other groups of the *Protozoa* (chiefly to the *Radiolaria*). The only traces of the past existence of the *Infusoria* which have been hitherto detected, are certain microscopic bodies which occur in the flints of the chalk formation, and which Ehrenberg considered to be the protective cases of *Peridinium* and allied forms of Flagellate *Infusoria.*

The *Infusoria* may be defined as *Protozoa which are typically provided with a mouth and rudimentary digestive cavity, which do not possess the power of emitting pseudopodia, but which are furnished with vibratile cilia, or with contractile filaments. They*

are mostly microscopic in size, the sarcode is differentiated into an ectosarc and an endosarc, and a nucleus and contractile vesicle are present.

The Infusorian animalcules are essentially unicellular, but they may form colonies, in which the separate units remain distinctly recognisable. The outer layer of the body is usually differentiated as a distinct membrane, sometimes thickened into a kind of test (as in *Peridinium* and *Ceratium*, fig. 33, D),

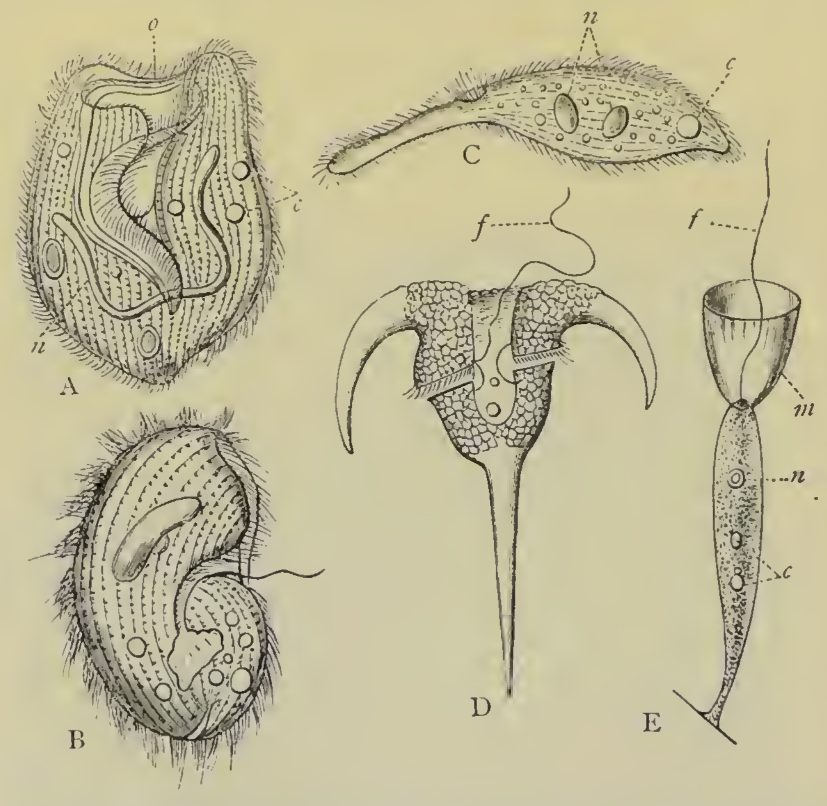


Fig. 33.—Ciliated, Cilio-flagellate, and Flagellate Infusoria. A, *Bursaria truncatella*, enlarged 50 times. B, *Nyctotherus cordiformis*, enlarged 150 times. C, *Amphileptus anser*, enlarged 120 times. D, *Ceratium tripos*, enlarged 250 times, with its carapace and single flagellum. E, *Monosiga angustata*, enlarged 2500 times: *n* Nucleus; *c* Contractile vesicle; *f* Flagellum; *m* Membranous collar surrounding the base of the flagellum. (After, or copied from, Saville Kent.)

and it carries vibrating cilia, lash-like "flagella," or contractile tentacles. In no case can pseudopodia be protruded. The sarcode of the body is typically differentiated into a firm outer layer (ectoplasm) and a more fluid central portion (endoplasm), and the former contains a nucleus and one or more contractile vesicles. The nucleus (fig. 33, *n*) varies much in form, being ovate, band-shaped, or necklace-like; and attached to its surface, or sunk in its substance, or not actually in contact with

it, is usually a smaller body known as the "nucleolus" or "paranucleus." The contractile vesicles (fig. 33, *c*) resemble in general structure the organs so named in the Rhizopods; but they sometimes appear to be connected with radiating canals, and may communicate with the exterior. The outer layer of the body may or may not be perforated by a permanent oral opening (fig. 33, *o*), and an anal aperture is also commonly present. From the common possession of a mouth, the *Infusoria* have been spoken of as the "stomatode" *Protozoa;* but a mouth is absent in many forms (such as the parasitic *Opalina*, many Flagellate *Infusoria*, &c.). Reproduction is asexual, and is effected by gemmation, or, more commonly, by fission with or without precedent conjugation.

The *Infusoria* may be divided into four orders—viz., the *Ciliata*, *Suctoria*, *Flagellata*, and *Cilio-flagellata*, of which the first comprises the majority of the members of the class.

I. Order Ciliata.—This order comprises those *Infusoria in which the outer layer of the body is more or less abundantly furnished with vibratile cilia, which serve either for locomotion or for the procuring of food.* Besides *cilia*, properly so called, some of the ciliated *Infusoria* are provided with *styles* or jointed bristles, which are movable, and subserve locomotion; whilst others have little hooks or *uncini*, with which they can attach themselves to foreign bodies. As types of the order, *Paramœcium* and *Vorticella* may be selected, the former being free, whilst the latter is permanently fixed in its adult condition.

Paramœcium (figs. 34 and 35) is a slipper-shaped animalcule, com-

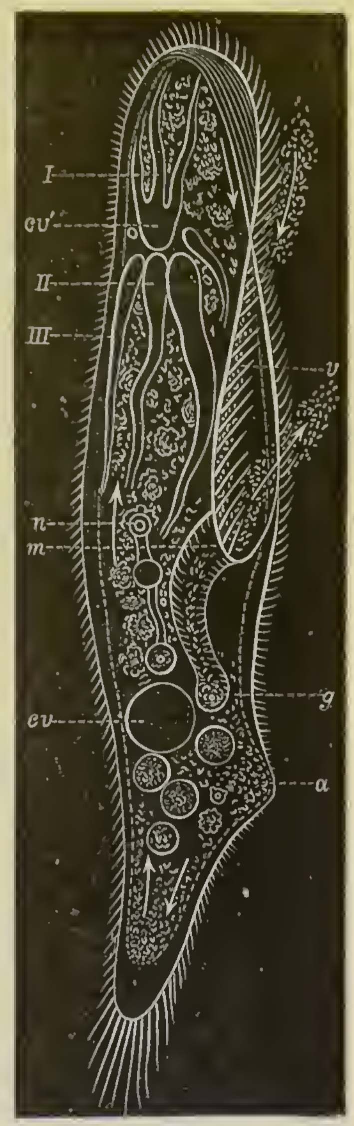


Fig. 34.—*Paramœcium*, viewed dorsally, and greatly magnified. *m* Mouth; *m* to *g* Gullet; *a* Anus; *cv'* and *cv* The contractile vesicles; I, II, III, Canals proceeding from the anterior contractile vesicle; *n* Nucleus; *v* Large cilia bounding the depression ("vestibule") leading to the mouth. The arrows indicate the course in which the particles of food circulate in the semi-fluid protoplasm of the interior of the body. (After James-Clark.)

posed externally of a structureless transparent pellicle — the "cuticle"—which is lined by a layer of firm and consistent sarcode (ectoplasm), which has been termed the "cortical layer," this in turn passing into a central mass of softer and more diffluent sarcode (endoplasm). The cuticle is merely the structureless hardened external lamina of the "cortical layer," and it may in some cases form a regular protective sheath (*Vaginicola*), a horny shell (*Codonella*), or even a reticulated siliceous envelope (as in *Dictyocysta*). Beneath the "cuticle" is the layer from which the cilia are given off, and below that, again, is a finely striated or fibrillated contractile layer ("myophane layer" of Haeckel), which corresponds physiologically to the muscles of higher animals. In some Infusorians (as in *Paramœcium* itself) there is a still more internal lamina of the "cortical layer," which is charged with the singular little organs known as "trichocysts." These are vesicular microscopic bodies, capable of emitting thread-like filaments, in many respects closely resembling the "thread-cells" of the *Cœlenterata*.

The "cuticle" in *Paramœcium* is covered with numerous rows of vibratile cilia (figs. 34 and 35), and is perforated by

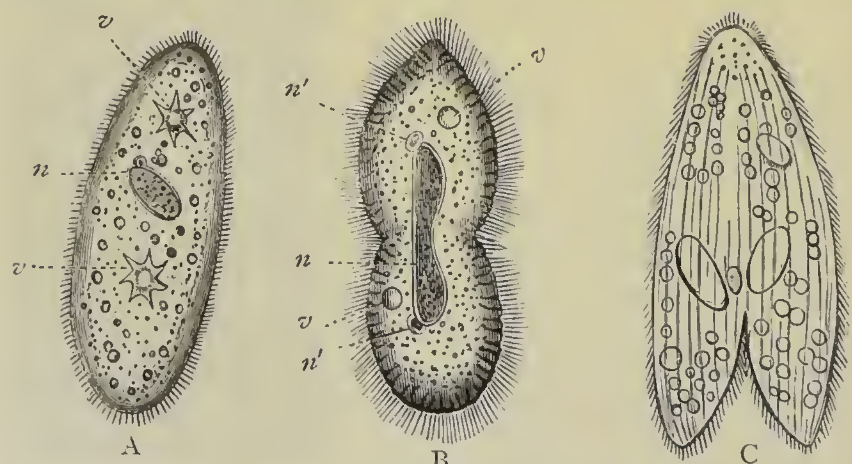


Fig. 35.—Ciliated Infusoria. A, *Paramœcium*, showing the nucleus (*n*) and two contractile vesicles (*v*). B, *Paramœcium bursaria* (after Stein), dividing transversely; *n* Nucleus; *n'* Nucleolus; *v* Contractile vesicle. C, *Paramœcium aurelia* (after Ehrenberg), undergoing "conjugation," two individuals being partially united by their ventral faces.]

the aperture of the mouth. The mouth leads into a funnel-shaped gullet, which is not continued into a distinct digestive sac, but loses itself in the soft central protoplasm. On the line of boundary between the cortical layer and the diffluent central sarcode are placed the "nucleus" and the "contractile

vesicle" (or vesicles). The "nucleus" is an oval body (in some forms band-shaped or rod-like), consisting of an outer membrane enclosing granular contents, and having a smaller spherical particle applied to its exterior. This latter is the so-called "nucleolus" or "paranucleus." The contractile vesicles (fig. 35, *v*) are clear spaces which dilate and contract at intervals, and which, when somewhat compressed, may exhibit a stellate outline. They sometimes show irregular radiating canals passing into the surrounding protoplasm, and they appear to sometimes communicate with the exterior. They are now usually regarded as corresponding with the water-vessels of various of the higher animals (such as the Rotifers), and as being excretory in function. Besides the contractile vesicles there are also more or less numerous non-pulsating vacuoles, often surrounding particles of ingested food. These perform a slow circulation along with the semi-fluid endoplasm in which they are contained. Ehrenberg regarded these vacuoles as so many stomachs, and it was in this belief that he gave the name of "Polygastric Animalcules" (*Polygastrica*) to the Infusorians. *Paramœcium* obtains its food by means of the currents of water which are set up by the vibrating cilia, and which sweep floating particles of all kinds from the surrounding water into the buccal funnel. Indigestible and fæcal matters are discharged by an anal aperture situated towards the hinder end of the body.

Reproduction in *Paramœcium* is effected either by simple fission, or after the temporary conjugation of two individuals. Simple fission is always transverse (fig. 35, B), the body becoming grooved across its middle, and ultimately divided into two similar portions. It was for long believed that *Paramœcium* divided itself also by longitudinal fission; but it is now known that this apparent longitudinal division (fig. 35, C) is really due to the conjugation of two independent individuals. In this process two *Paramœcia* come together, and adhere closely to one another by their ventral surfaces, becoming, in fact, partially fused with one another, in which condition they remain for some days, when they again separate and resume their individual existence. During and subsequent to this temporary amalgamation, the nucleus and paranucleus of each enlarges, and the latter assumes a striated appearance. Both the nuclei and paranuclei ultimately divide into smaller bodies, some of which disappear or are ejected from the body, while others are retained to form new nuclei and paranuclei. The phenomena just described were originally believed to indicate a kind of sexual reproduction, in which the nuclei played the

part of ovaries, and the paranuclei of testes; but it is clear that this is an erroneous view of the process. Upon the whole, it would seem rather that the process is one in which the nucleus undergoes regeneration by portions of the para-nucleus, and that its result is that each of the conjugating individuals undergoes repeated fission subsequent to their separation from each other.

Vorticella (fig. 36, C) is a beautiful flower-like Infusorian which is commonly found in fresh water, adhering to the stems of aquatic plants. It

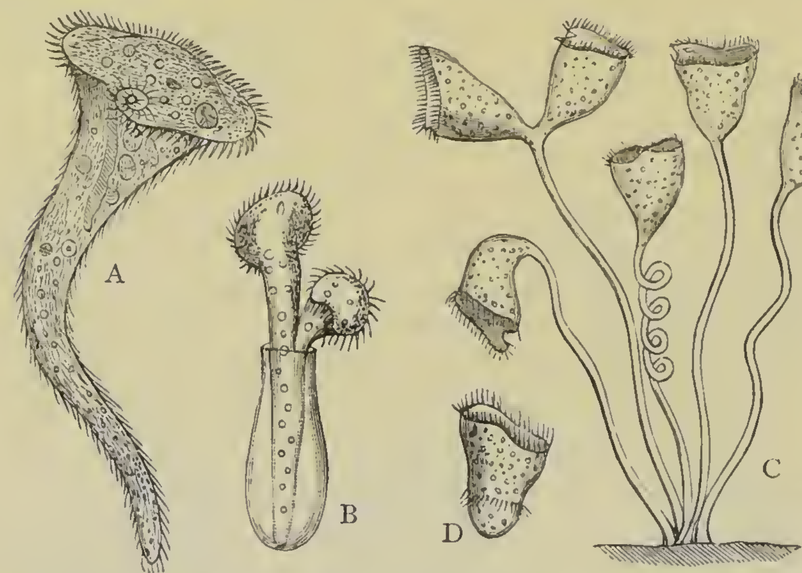


Fig. 36.—A, *Stentor Mülleri*; B, *Vaginicola crystallina*; C, Group of *Vorticellæ*; D, Free calyx of *Vorticella*, produced by fission, showing the posterior circlet of cilia.

consists of a bell-shaped body or "calyx," supported upon the extremity of a slender contractile stem or "pedicle." The other extremity of the pedicle is fixed to some foreign body, and its power of contraction is due to the presence in its interior of a spiral contractile fibre, which is sometimes called the "stem-muscle." The edge of the bell or calyx is surrounded by a projecting rim or border, called the "peristome," within which is a circular surface, the "disc," forming the upper extremity of the so-called "rotatory organ." The disc is surrounded by a fringe of vibratile cilia, forming a spiral line which is prolonged into the commencement of the digestive canal. Near the edge of the disc is situated the mouth, which conducts by its entrance or "vestibulum" into a fusiform canal or "pharynx," which terminates abruptly in the central endoplasm. The particles of food are taken in at the mouth, descend through the short alimentary canal, and enter the soft endosarc, where they are subjected to the general rotation of the endoplasm, being finally excreted by an anal aperture which is situated near the mouth and within the vestibule. As in *Paramœcium*, the body in *Vorticella* is composed of an outer "cuticle," a central endoplasm, and an intermediate "cortical layer," which contains a contractile vesicle and a band-like nucleus.

Reproduction in *Vorticella* may take place by fission, or by gemmation. In the first of these modes, the calyx, having previously passed into a contracted and quiescent condition, becomes indented in a longitudinal direction—viz., from the pedicle to the disc; and the groove thus formed becomes gradually deeper until the calyx is finally divided into two halves supported upon the same pedicle. On one of these cups a "posterior" circlet of cilia is then formed, in addition to the "anterior" circlet already existing (*i.e.*, a fringe of cilia is developed round that end of the calyx which is nearest the attachment of the pedicle and furthest from the disc). The cup (fig. 36, D), thus furnished with a circlet of cilia at both extremities, is then detached, and swims about freely. Finally, having found a suitable resting-place, the new calyx fixes itself by its posterior extremity, develops a stalk, and loses its temporary hinder ring of cilia, thus becoming converted into a sedentary individual.

In the process of gemmation, a bud is thrown out from the hinder extremity of the calyx of a normal stalked *Vorticella*, which ultimately forms a small free calyx, furnished with a hinder circlet of cilia, just as is seen in the fissiparous process of development. The locomotive bud thus produced attaches itself to an ordinary stalked calyx belonging to another individual, and becomes fused therewith; the process being followed by encystation. The result of this conjugation and subsequent quiescence is the active subdivision of the now rejuvenated calyx.

Closely allied to *Vorticella*, and like it represented by many species, both in fresh and salt water, is the genus *Epistylis*, in which the organism forms a tree-like colony of numerous ciliated calyces attached to a rigid, non-contractile, branched stem.

Carchesium is another form which is like *Epistylis* in consisting of a number of calyces supported upon a branched pedicle, but differs from *Epistylis* and agrees with *Vorticella* in the fact that the pedicle is contractile.

Stentor, or the trumpet-animalcule (fig. 36, A), is another common Infusorian which is closely related to *Vorticella*. It consists of a trumpet-shaped calyx, devoid of a pedicle, but possessing the power of attaching and detaching itself at will. When detached it swims by means of the anterior circlet of cilia, just as the calyx of *Vorticella* will if broken from its stalk. In *Vaginicola* (fig, 36, B) the essential structure is much the same as in *Vorticella*, but the body is protected by a membranous or horny case ("carapace" or "lorica"), which is formed by a hardening of the cuticle, and within which the animal can retire.

II. Order Suctoria.—This order includes a series of *Infusoria* of a very anomalous nature. In *Acineta* or in *Podophrya* (fig. 37, A), which may be taken as types, the body is provided with a number of radiating filamentous tubes, which are furnished at their extremities with suctorial discs, and are capable both of exsertion and retraction. These retractile tubes seize the prey and usually also serve as vehicles for the ingestion of food: hence the term of "polystome," or many-mouthed Infusorians, has been proposed for the order by Professor Greene. A nucleus and one or more contractile vesicles are present, but there are no cilia in the adult condition, and the body is fixed to some foreign object by a stalk-like extension of the cortical layer.

III. Order Flagellata.—This order comprises those *In-*

fusoria in which the body is provided with one or more long whip-like filaments or "flagella," the movements of which create currents in the surrounding water, and thus bring food

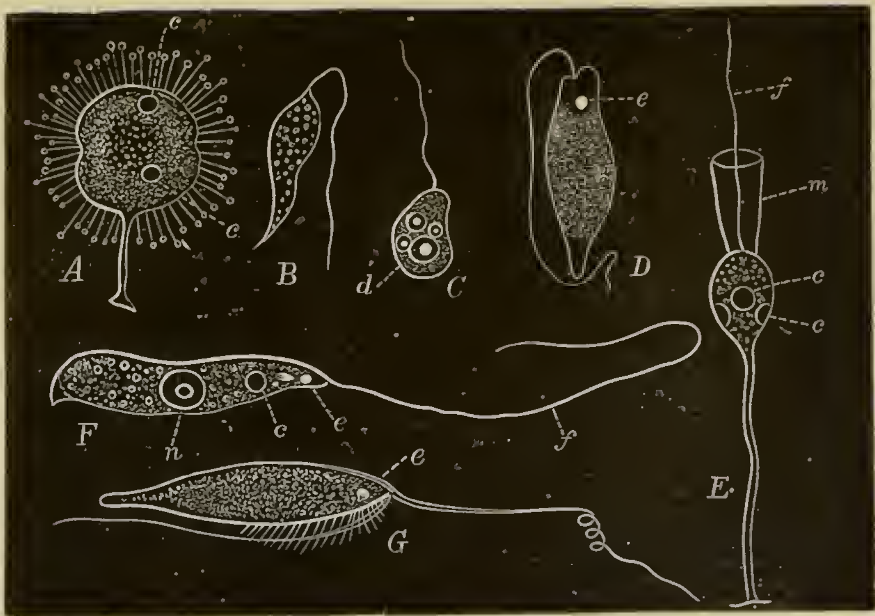


Fig. 37.—Suctorial, Flagellate, and Cilio-flagellate Infusoria. A, *Podophrya*; B, *Cercomonas truncata*; C, *Monas neglecta*; D, *Euglena sanguinea*; E, *Codosiga pulcherrima*; F, *Astasia trichophora*; G, *Heteromastix proteiformis*. *f* Flagellum; *m* Collar at the base of the flagellum; *c* Contractile vesicle; *n* Nucleus; *e* Eye-spot. (After Pritchard, Ehrenberg, and James-Clark.)

to the animal. In the free forms, the flagella serve likewise as locomotive organs. In the typical *Flagellata* the general structure of the body resembles that of the Ciliated Infusorians—a cuticle, ectoplasm, and soft endoplasm being recognisable, while a nucleus and one or more contractile vesicles are present.

The precise limits of the order *Flagellata* cannot at present be accurately laid down; as there are many organisms (such as the Monads, the *Volvocidæ*, *Euglena*, &c.) which occupy a somewhat doubtful position, resembling animals in certain characters, while in others they approach the plants. The most typical group of the order is that of the "Collar-bearing" *Flagellata* (*Choano-flagellata* of Saville Kent), comprising minute Infusorians, in which the base of the flagellum is surrounded by a cup-like or cylindrical membranous "collar," which can be retracted at will (fig. 33, E; and fig. 37, E). The disc-like space of protoplasm at the base of the collar is soft, and serves for the inception of food, particles of which are brought into the collar by the currents in the surrounding

water, which are set up by the lashing movements of the flagellum. Some of these collar-bearing Monads are simple, with the body naked and free, or attached to some foreign object by a short stalk. Others form composite growths or colonies, often much branched; and in many cases, again, the body is not naked, but is protected with a kind of shell or "lorica." The collar-bearing *Flagellata* are particularly interesting from the close structural resemblance which they bear to the flagellated cells which line the so-called "ciliated chambers" of the Sponges.

In another group of forms now referred to the *Flagellata* (such as *Astasia* and *Euglena*, fig. 37, D and F), the flagellum has no collar at its base, and there is a definite oral opening for the inception of food. Many of these types possess a singular brightly-coloured mass of pigment in the interior of the body, which is known as the "eye-spot," and may possibly be a species of sense-organ. Also belonging to this group are the curious animalcules which form the genus *Noctiluca*. The common *Noctiluca miliaris* reaches a length of as much as $\frac{1}{20}$th of an inch, and abounds in most oceans, being one of the principal sources of the diffused luminosity of the sea.

In yet another group of the *Flagellata*, comprising the minute microscopic organisms usually known as "Monads" (fig. 37, C), the flagellum is without a basal collar, and food may be taken in at any part of the surface, no definite mouth being present. In many respects the Monads closely approach the unicellular *Algæ*, and they have often been regarded as belonging to the vegetable kingdom.

IV. Order Cilio-Flagellata.—The *Infusoria* included in this order are very closely related to the typical *Flagellata*, from which they differ in the fact that cilia are developed in addition to the flagellum. A distinct mouth is usually present, and there is no collar at the base of the flagellum. In some cases (*Heteromastix*, fig. 37, G) there are two flagella. The cilia usually line a groove in the integument, often having the form of a transverse girdle (fig. 33, D); but they are sometimes diffused. The body may be naked, but is often protected by a sort of buckler or test of horn, often prolonged into long processes, as is seen in *Ceratium* (fig. 33, D). The Cilio-Flagellate Infusorians are found both in fresh and salt water, and the genera *Peridinium* and *Ceratium* include some of the most common and characteristic types.

LITERATURE.

[In the subjoined list, as well as in those which will be subsequently given, it is hardly necessary to say that nothing further will be attempted than to furnish the student with a brief and limited *selection* from the numerous works and memoirs relating to the animals belonging to each subkingdom. It has also not appeared needful to cite the names of well-known manuals and text-books of zoological science, save where these contain special information.]

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CHAPTER VI.

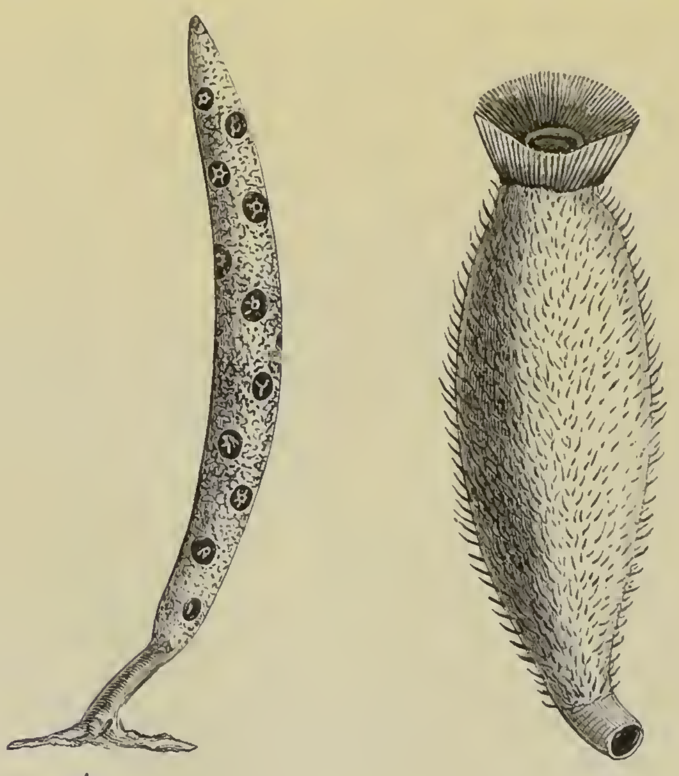
PORIFERA.

UNDER the name of *Porifera* are included all those singular organisms which are commonly known as Sponges. Originally regarded as being of a vegetable nature, the Sponges are now universally admitted to be animals; though naturalists are not yet in absolute agreement as to the precise position in the animal kingdom which ought to be assigned to them. Owing to the close likeness of some of the cell-elements of the Sponges to certain of the *Protozoa*, the entire group has been often referred to this latter sub-kingdom. Thus, some of the cells of a sponge are morphologically identical with the *Amœbæ*, while others present the closest possible resemblance to the Flagellated *Infusoria*. Hence, a sponge has often been regarded as being a kind of colony, the units of which are morphologically Protozoans. Naturalists are, however, now agreed as to the removal of the Sponges from the *Protozoa;* and they are by many authorities regarded as forming the lowest division of the Zoophytes (*Cœlenterata*). Other authorities consider that the Sponges represent a distinct morphological type, intermediate between the *Protozoa* and the *Cœlenterata*, and that they are, therefore, entitled to take rank as a separate sub-kingdom, to which the name of *Porifera* has been given. In the present state of our knowledge, this view seems to be the one which is attended with the fewest difficulties, and it will, therefore, be followed here.

The Sponges may be defined as *multicellular organisms of variable shape, the cells of which are typically disposed to form an outer membrane, an inner membrane, and an intermediate stratum; and which are traversed by canals, which open on the surface, and which are more or less extensively lined by flagellate cells. In most cases the cellular aggregate is supported by a framework of horny fibres, or of flinty or calcareous spicules. A definite mouth*

and stomach are wanting, and a nervous system is not known with certainty to be developed.

Regarded from a general point of view, a sponge differs from the *Protozoa*, and agrees with all the higher animals (*Metazoa*) in the fact that the body is multicellular, being composed of numerous protoplasmic units, which have been termed "sponge-particles" or "sarcoids," but which may be best spoken of simply as "sponge-cells." In the Sponges, therefore, we meet, for the first time, with definite "tissues," though the nature of these is simpler and less complicated than is found to be the case in the higher animals. The entire aggregate of cells is traversed by a system of canals, which open on the surface by two sets of apertures ("pores" and "oscula"),



A B

Fig. 38.—A, *Axinella polypoides*, a fibrous Sponge, showing oscula and pores; B, *Sycandra ciliata*, a calcareous Sponge, showing the single terminal osculum. (After Schmidt.)

by which water is admitted into the organism, and again expelled from it. The circulation of water is maintained by flagellated cells, which are usually disposed in the interior of definite dilatations ("flagellated chambers") of the canals; and it is by means of these that the organism obtains food, and

carries on the processes of respiration and excretion. There is, therefore, no proper mouth, nor is there a definite stomach, in the sense in which the higher animals can be said to possess this structure. As a rule, lastly, the entire cellular aggregate is strengthened and endowed with a definite form by the development in it of a "skeleton" of variable form and composition.

The general organisation of the Sponges being as above indicated, it is next necessary to consider in greater detail the separate structures which compose the sponge body, and the manner in which these are arranged. In the first place, as regards the soft parts ("sponge-flesh"), those sponges which have been most thoroughly investigated exhibit a threefold division of their cells. Certain of the cells form an external membranous investment (the so-called "ectoderm") to the sponge; others line all the internal canals (constituting what is known as the "endoderm"); while others occupy all the spaces between the outer membrane on the one hand, and the canal-system on the other hand (forming what is known as the "mesoderm").

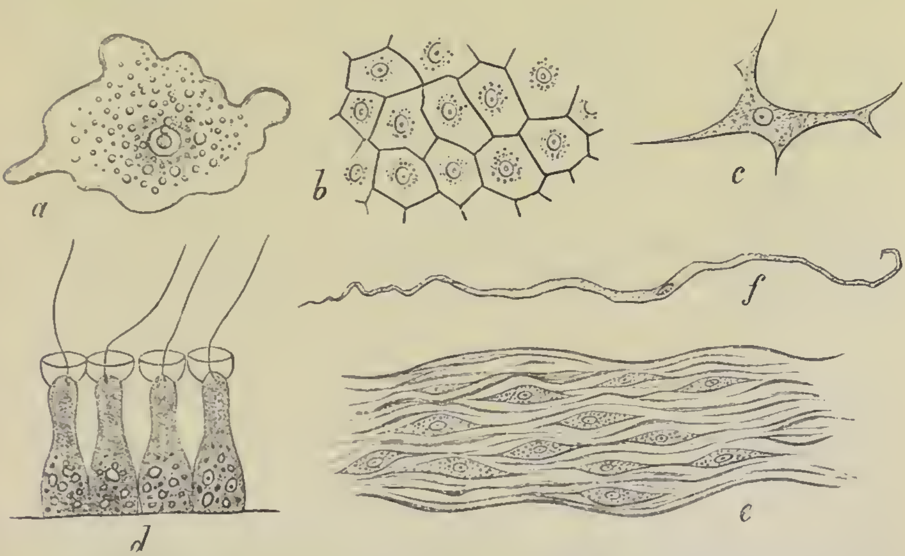


Fig. 39.—Cell-elements of Sponges. *a* Amœboid cell of *Spongilla*; *b* Flattened pavement-cells of the ectoderm of a Sponge; *c* Connective-tissue cell of the mesoderm; *d* Flagellate collar-bearing cells of *Sycon raphanus*; *e* Sponge-flesh of the cortex of *Thecophora semisuberites*, showing connective-tissue cells and intercellular tissue; *f* Contractile fibre-cell of *Craniella*. Greatly magnified. (After Kölliker, Fr. Schultze, and Vosmaer.)

The ectoderm covers the external surface, and is prolonged into the "inhalant canals." It is composed of flattened, polygonal, nucleated epithelial cells (fig. 39, *b*), which are united to one another by their edges. The inner membrane or "endoderm" is also composed of epithelial cells,

the form and characters of which vary in different sponges, or in different parts of the same sponge. The most characteristic of these endodermal cells are oval or elongated in shape, with a nucleus and one or two contractile vesicles, and having attached to the free end a single lash-like flagellum, the base of which is surrounded by a delicate membranous funnel or "collar" (fig. 39, *d*). These cells play an important part in the life of the sponge, and will be spoken of later in dealing with the so-called "flagellated chambers."

The general "sponge-flesh," comprising the substance of the sponge between the outer and inner epithelia, is made up of gelatinous connective-tissue, in the form of cells embedded in a more or less copious intercellular substance (fig. 39, *e*). Many of the cells of this fundamental tissue are without definite walls, and have the power of throwing out pseudopodia, and thus of changing their form (fig. 39, *a* and *c*), presenting, therefore, a close resemblance to *Amœbæ* in their characters. These "amœboid" cells often change their place, and wander from one part of the sponge-flesh to another. In addition to these are found fusiform cells, stellate cells, pigment cells, and other varieties of cellular tissue. Definite nerve-cells have not yet been detected, but some of the cells become modified into contractile fibres (fig. 39, *f*), which appear to represent the muscles of the higher animals.

The entire aggregate of sponge-cells is so arranged as to be traversed by a series of canals, which convey water in and out of the organism, and which are thus connected with respiration and the procuring of food. Looking at the skeleton of a dried sponge, the most obvious sign of the existence of this "aquiferous system" is the presence of one or more large superficial openings, together with a great number of much smaller apertures (fig. 38). These latter are termed the "pores," and though permanently present in the skeleton, they are only temporarily present in the soft parts, being produced afresh, when required, as openings between the sponge-cells of the ectodermal layer. The "pores" (fig. 40, A, *p*) open directly, or through the intervention of more or less extensive subdermal cavities, into a series of canals, which ramify in every direction through the sponge, and which are called "inhalant canals," as it is through these that the water is conveyed to the interior of the sponge. The "inhalant canals" ultimately open into a second series of canals, which converge to form one or more large tubes which open on the surface by a corresponding number of large openings. These large tubes (fig. 40, A, *e*) carry the water out of the organism again, and they are hence called "exhalant canals"; while their surface-openings are known as the "oscula." The "oscula," though capable of being temporarily closed, are permanent, and are often placed on chimney-like elevations. If there should be but one osculum, it is placed at the apex of the sponge (fig. 38, B), while the pores occupy the general external surface. What is

commonly called a "sponge" may consist of only a single excretory opening or "osculum," together with the "pores" belonging to this (fig. 38, B); or it may consist of a larger or smaller number of such "oscula," each with its proper com-

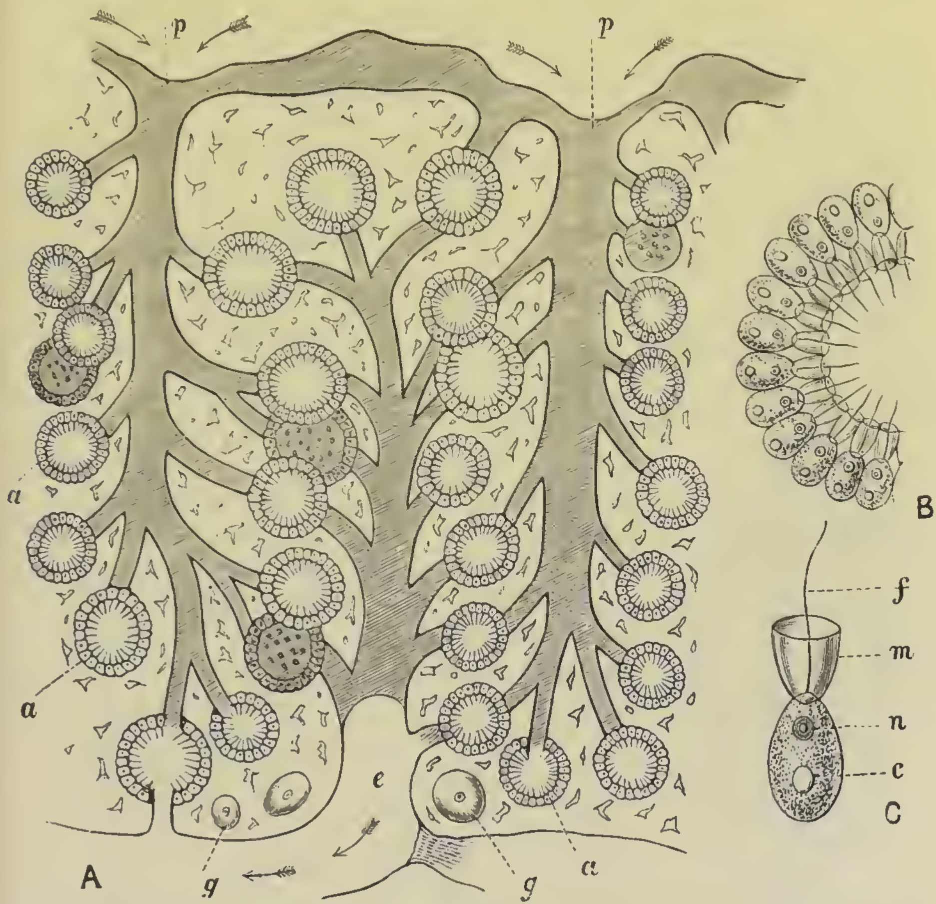


Fig. 40.—Structure of Spongida. A, Vertical section of the outer layer of *Halisarca lobularis*, a Sponge in which the skeleton is wanting, enlarged 75 times (after F. E. Schultze): *p p* "Pores," or openings of afferent canals by which water is conducted to the flagellated chambers or "ampullaceous sacs" (*a a*); *e* Commencement of a larger efferent canal, conducting from the flagellated chambers to the deeper canals, by which the water is finally carried off to be expelled from the "oscula"; *g g* Young stages of the reproductive bodies or spores. B, Part of a single flagellated chamber of the same Sponge, transversely divided, and enlarged 800 diameters (after Saville Kent), showing the flagellate cells or "sponge-particles," with their inwardly directed flagella. C, A single flagellate cell of the same, still further enlarged: *f* Flagellum; *m* Collar round the base of the flagellum; *n* Nucleus; *c* Contractile vesicle.

plement of "pores" (fig. 38, A). In the latter case, each osculum, with its accompanying pores, constitutes a "person," and the entire organism is known as a "sponge-stock."

In a living sponge, in its active condition, a circulation of water is kept up throughout the organism by means of this

canal-system. The water is admitted by means of the "pores," is driven into the interior of the sponge, and is finally expelled in steady streams from the osculum or oscula. The mechanism by which this circulation of water is effected was long unknown. It is now known, however, that the circulation of water is maintained by the vibrations of the flagella, with which certain of the sponge-cells are provided. In the most typical cases, the initial branches of the "exhalant canals" are dilated into globular or elongated chambers (fig. 40, A, *a a*), which are lined with flagellate sponge-cells. Each of these flagellate cells possesses a nucleus and one or two contractile vesicles, and is furnished with a single flagellum, and a basal membranous collar (fig. 40, C); thus coming to entirely resemble a simple Flagellate Infusorian. The collar-bearing cells are so disposed within these "flagellated chambers" (or "ciliated chambers," as they are sometimes called), that all their flagella point inwards towards the centre of the chamber (fig. 40, B), and they all work towards the interior of the sponge, and thus supply the motive-power needed for keeping up the water-currents. From the streams of water thus kept circulating through the sponge the organism obtains oxygen, while the individual sponge-cells appropriate the minute particles of nutrient matter which may be carried in the water. Waste matters are also carried off by the outgoing water-currents. By many authorities, the flagellated cells are regarded as being the ones more especially concerned in the nutrition of the organism; but this view is rejected by others.

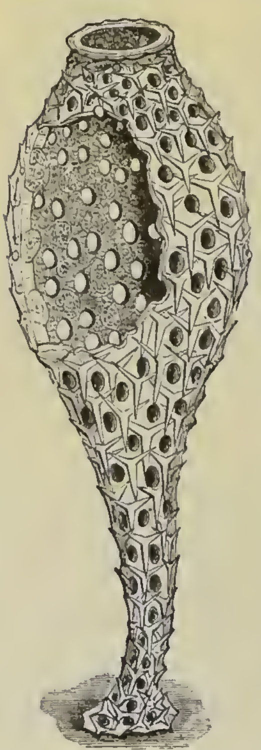


Fig. 41.—*Ascetta primordialis*, a simple calcareous Sponge, enlarged 50 times. (After Haeckel.)

The above is the typical arrangement of the canal-system in the Sponges, but it is subject to variations in different groups of sponges. The simplest type of the aquiferous system is seen in certain of the *Calcispongiæ*, such as *Ascetta* (fig. 41). In this form the organism is pear-shaped, with a thin outer wall enclosing a large central cavity. At the summit of the sponge is the single large osculum, and the whole of the outer wall is pierced by innumerable pores. There is no proper canal-system, or but a rudimentary expression of such, since the pores simply traverse the thin outer wall, and open into the

large central cavity. There are thus no proper "flagellated chambers," but the endoderm lining the whole central cavity is composed of flagellated cells. The central chamber may thus be compared to a single large flagellated chamber, which opens externally by the apical osculum.

In a few sponges (the *Myxospongiæ* of Haeckel) there is no skeleton, and the above description would, therefore, fully express the general structure of the organism. In the vast majority of sponges, however, the soft cellular body is supported by more or less extensively developed hard structures, which collectively constitute the *skeleton*. The nature of the skeleton varies greatly in different forms, and these variations have been largely made use of in the identification and classification of the Sponges. Speaking generally, the skeleton has the form of a more or less coherent framework, composed either of horny fibres, or of needles of mineral matter, or of both these elements in combination. The different modifications of the skeleton will be more particularly spoken of in dealing with the different groups of sponges. It will be sufficient to point out here that, apart from modifications in the *form* of the skeletal elements, there are the following four principal types of skeleton among the Sponges:—

1. In certain sponges (such as the Common Bath Sponges) the skeleton is wholly composed of netted horny fibres, without proper "spicules." The substance composing the fibres in such types is allied to horn, but not precisely of the same nature, and it is known as "spongin" or "keratode."

2. In another group of sponges, including most of the commoner forms, the skeleton is more or less extensively composed of siliceous needles of "spicula," of various forms. These spicules may be embedded in various ways in a reticulated fibrous skeleton of spongin; or the horny material may be greatly reduced, so that the skeleton-fibre consists essentially of minute flinty needles.

3. In a third group of sponges, the skeleton is destitute of horny matter, and consists wholly of siliceous spicules, which may be fused with one another into a continuous framework, or may be so interlocked by their ends as to produce practical rigidity. In both this group and the preceding, in addition to the proper skeleton, there are developed in the mesoderm numerous microscopic needles of flint, which are known as "flesh-spicules."

4. Lastly, there is a group of sponges in which the skeleton is wholly made up of spicules of carbonate of lime.

Reproduction and Development.—Reproduction in the Sponges may be affected either sexually or non-sexually. In the

sexual method of reproduction, certain of the cells of the mesoderm become converted into ova, while the spermatozoa are developed in clusters in the mesoderm. The actual fertilisation of the ova by the spermatozoa has not yet been certainly observed. The ova are usually liberated from the sponge through the medium of the exhalant canals. In the asexual method of reproduction groups of mesoderm-cells become segregated, and surrounded by a spiculated capsule, when they constitute the so-called "gemmules." These gemmules ultimately are liberated from the parent sponge, when the contained sponge-cells escape with the water through an opening in the wall of the capsule, and become developed into a new sponge.

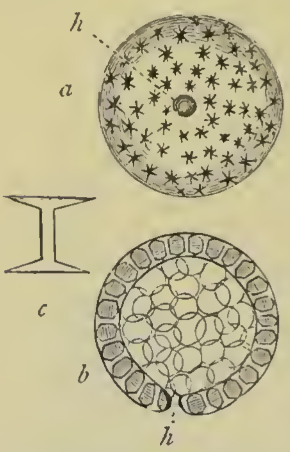


Fig. 42.—*a* Gemmule of *Spongilla; h* Hilum; *b* Diagrammatic section of the gemmule, showing the outer layer of amphidiscs and the inner mass of cells; *c* One of the amphidiscs seen in profile.

The process of reproduction by means of "gemmules" was first accurately observed in the fresh-water sponges (*Spongilla*), but it occurs in many marine types as well. If a *Spongilla* be examined in winter, its deeper portions will be found filled with the small seed-like "gemmules," each of which possesses a small aperture or "hilum" at one point (fig. 42, *a*). Each gemmule is composed of an outer coriaceous capsule surrounded by a layer of peculiar asteroid spicula, resembling two toothed wheels united by an axle, and termed "amphidiscs" (fig. 42, *b*, *c*). These amphidiscs are embedded in sarcode, whilst their inner surfaces rest upon the tesselated capsule already mentioned. In the interior of the capsule thus formed is a mass of cells, which, on the coming of spring, is extruded through the hiliform opening of the capsule into the water, and becomes developed into a young *Spongilla*.

As regards the *development* of the sponges, the impregnated ovum (fig. 43, A) cleaves, by the usual process of "segmentation," into a mass of primitive cells. In the most usual mode of development, the embryonic cells become divided into two distinct groups, one of which ultimately forms the external layer (ectoderm), whilst the other forms the internal layer (endoderm). As described by Metschnikoff in the embryo of *Sycon,* these groups of cells at first form the two poles of the larva, the cells of the endoderm being flagellated (fig. 43, B, *c*), and enabling the organism to swim actively through the water, whilst the cells of the ectoderm are non-flagellated (fig. 43, B, *b*). In the interior of the embryo is a central cavity (the "segmentation cavity"). In the process of growth, the flagellated endodermal cells become gradually retracted into the interior of the larva (fig. 43, C and D), till the body becomes completely invaginated upon itself. In this condition (fig. 43, E) it forms what Haeckel terms a "gastrula," and consists of two layers of cells, an outer and an inner, enclosing a central cavity, which communicates with the outer water by a single primitive opening. This aperture is formed by the invagination of the body, and not by rupture of the walls of the central cavity. The central cavity of the gastrula is not the primitive "segmentation-cavity," this

having been obliterated in the process of invagination, but it is an entirely new cavity. In its further development, a mesoderm is developed between the two primitive embryonic layers, and in this the primordial spicules of the skeleton are produced. The embryo next fixes itself to some foreign

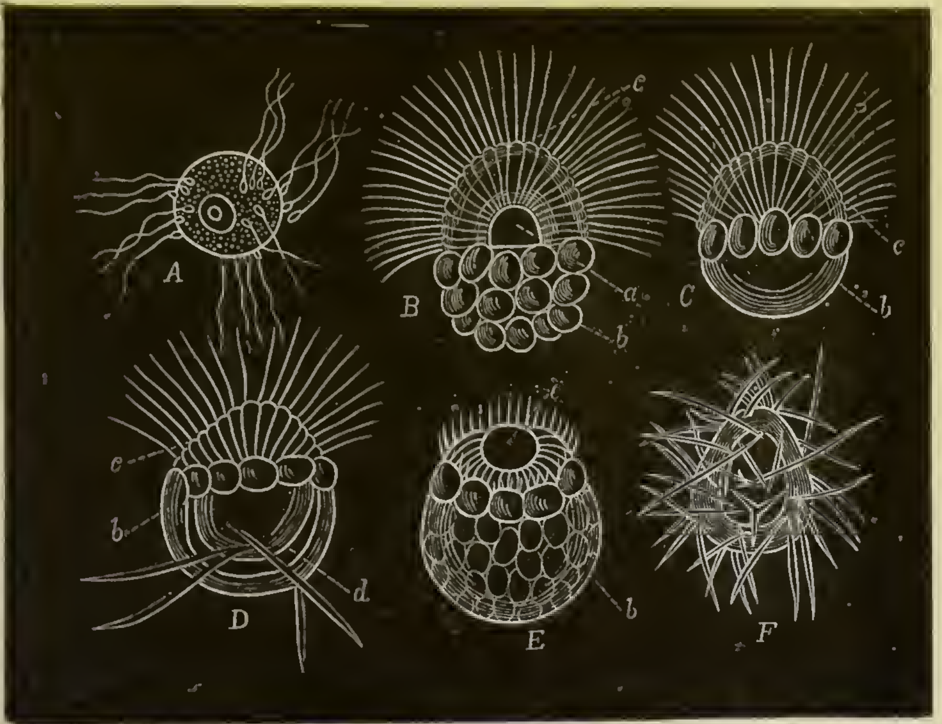


Fig. 43.—Development of *Calcispongiæ*. A, Ovum in the act of being impregnated by the spermatozoids. B, Free-swimming embryo of *Sycon*, showing the non-flagellated ectodermal cells, and the flagellated endodermal cells, the latter enclosing a temporary "segmentation-cavity" (*a*). C, The embryo further advanced, with the flagellated half of the body reduced in size. D, The embryo at a later stage, showing the primitive spicules, and the commencing body-cavity (*d*). E, Unattached larva, without the skeleton; the flagellated endoderm has now been withdrawn within the non-flagellated ectoderm, and the primitive opening into the body-cavity (*e*) has been formed by invagination. F, Young *Sycon*, six days old, showing the skeleton. *b* Non-flagellated ectodermal cells; *c* Flagellated endodermal cells. (A is after Haeckel; B, C, D, E, and F are after Metschnikoff.)

object by that extremity of the body at which the mouth is situated; its walls become perforated by pores; and an osculum is produced at its free end—the embryo now becoming converted into a simple type of sponge, such as is represented permanently by *Ascetta* (fig. 41).

Classification of the Sponges.—There is, perhaps, no single group of the animal kingdom in which it has proved so difficult to establish a natural classification, as has been found to be the case with the Sponges. Even at the present day there is no extant classification which can be regarded as final. It is, however, now generally admitted that the Calcareous Sponges are so far separated from all the other groups of sponges as to properly constitute a distinct *class* of sponges.

The non-calcareous sponges may be grouped together in a second class under the name of *Plethospongiæ*, proposed for them by Professor Sollas. As regards the ordinal divisions of the *Plethospongiæ*, the grouping followed by Professor Zittel may be adopted, and the general classification of the Sponges is thus expressed in the following table:—

SUB-KINGDOM PORIFERA.

CLASS I. PLETHOSPONGIÆ (Sollas).

Order 1. MYXOSPONGIÆ (*Halisarca*).
" 2. CERATOSPONGIÆ (*Euspongia*).
" 3. MONACTINELLIDÆ (*Halichondria*, &c.)
" 4. TETRACTINELLIDÆ (*Geodia*, *Tethya*, &c.)
" 5. LITHISTIDÆ (*Discodermia*, &c.)
" 6. HEXACTINELLIDÆ (*Holtenia*, &c.)

CLASS II. CALCISPONGIÆ.

Family 1. ASCONES (*Ascetta*, &c.)
" 2. LEUCONES (*Leucandra*, &c.)
" 3. SYCONES (*Grantia*).
" 4. PHARETRONES (*Corynella*, &c.)

CLASS I. PLETHOSPONGIÆ.

The Sponges included in this class are occasionally destitute of hard structures, but the great majority possess a skeleton, which may be composed of horny fibres alone, or of siliceous spicules alone, or which is formed by a combination of these two sets of structures. In no case is the skeleton composed of carbonate of lime.

ORDER 1. MYXOSPONGIÆ.—The sponges of this order are characterised by the total absence of skeletal structures. The type-genus is *Halisarca*, comprising soft fleshy sponges, often brilliantly coloured, which form crusts upon submarine objects.

ORDER 2. CERATOSPONGIÆ.—In this group of sponges the skeleton is composed entirely of the horny substance known as "spongin," no proper spicules being developed. The type of this group is the common Turkey Sponge (*Euspongia officinalis*). The horny fibre of the skeleton forms a close reticulation or network (fig. 44, A), and can be shown to consist of a delicate axial thread of organic matter surrounded by a laminated sheath. Though there are no true spicules in the *Ceratospongiæ*, the horny fibre very generally includes numerous

sand-grains or other foreign bodies in its interior (fig. 44, B), these being taken in at the free growing ends of the fibres, to which they form a kind of core, replacing the soft organic

Fig. 44.—Forms of skeleton in the fibrous Sponges. A, Horny, non-spiculate skeleton of the Bath Sponge, enlarged about fifty times. B, Horny fibre cored with sand-grains. C, Horny fibre with projecting siliceous spicules ("Echinonematous" Sponge). D, Fibre in which the spongin has been more or less completely replaced by siliceous spicules ("Holorhaphidote" Sponge). B, C, and D are greatly enlarged, and are after Carter.

axis which in some cases is alone present. All the *Ceratospongiæ* are marine, and are found in warm seas. The true Turkey Sponge (*Euspongia officinalis*) is found in the Mediterranean, as is also the great Bath Sponge (*Hippospongia equina*). Allied forms are found in the seas round the West Indian Islands.

ORDER 3. MONACTINELLIDÆ.—This order comprises a very large number of recent sponges, all of which possess a skeleton which is typically composed of horny fibres with included spicules of flint. The spicules vary much in form, but are always uni-axial, being most commonly fusiform, pin-shaped, or bow-shaped (fig. 45, *a*, *b*, *c*). The proportion borne by the spicules to the horny fibre is very variable, and in some types the skeleton consists almost wholly of uni-axial spicules without any, or with very little, horny connecting-substance (fig. 44, D). In addition to the spicules contained in the horny skeleton-fibre, there are developed in the mesoderm more or less numerous siliceous spicules, which lie loose, and which are known as "flesh-spicules," and which are also uni-axial in form.

A very large number of the commoner marine sponges belong to this order. The universally distributed "Bread-

crumb" Sponge (*Amorphina panicea*) of British coasts is a good example of the order. Another well-known type is the common Boring Sponge (*Cliona*), which forms winding and irregularly swollen canals in the substance of shells. Similar burrows have been found in fossil shells from rocks as old as the Silurian; so that the group of the Monactinellid Sponges is one of great antiquity.

A remarkable group of *Monactinellidæ* is that of the Fresh-water Sponges, of which the common *Spongilla fluviatilis* of our rivers and lakes is a well-known representative. This species forms irregular crust-like or plant-like masses, usually of a more or less green colour. The spicules (fig. 45, *c*) are

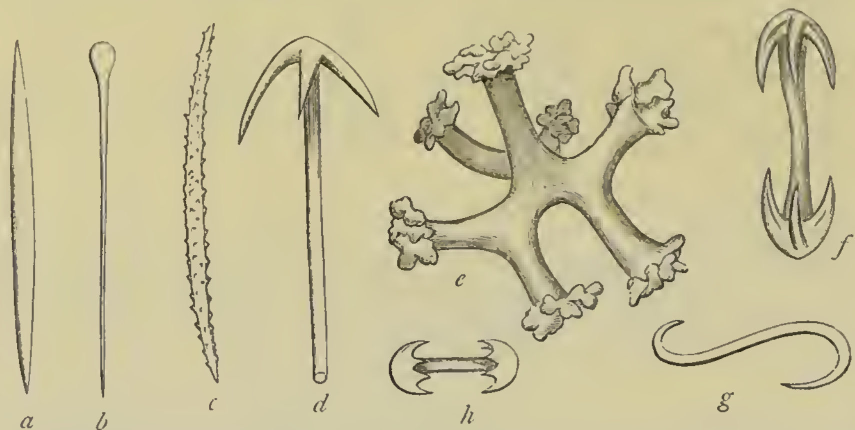


Fig. 45.—Spicules of Sponges. *a* Monactinellid skeleton-spicule of *Reniera*; *b* Monactinellid spicule of *Cliona*; *c* Monactinellid spicule of *Spongilla*; *d* Tetractinellid skeleton-spicule of *Geodia*; *e* Skeleton-spicule of a Lithistid Sponge (*Jerea*); *f* Flesh-spicule of *Cribella*; *g* Flesh-spicule of *Esperia*; *h* Flesh-spicule of *Hyalonema*. All the figures are greatly enlarged. (After Schmidt, Vosmaer, Zittel, &c.)

linear, pointed at both ends, slightly curved, and either smooth or covered with minute projecting spines. Reproduction takes place not only sexually, but also by the formation of numerous "gemmules," or winter-eggs, as has been previously described. Fresh-water Sponges, belonging either to the genus *Spongilla* or to allied types, are found in almost all parts of the world.

ORDER 4. TETRACTINELLIDÆ.—This order includes marine Sponges, which agree with the preceding in the fact that the skeleton consists of siliceous skeleton-spicules and that "flesh-spicules" are present, but differ in the fact that the principal spicules of the skeleton are tetraxial. The commonest form of spicule is that of an elongated rod carrying three shorter rays at its upper end (fig. 45, *d*). Besides the typical tetraxial spicules, there are other monaxial forms, as well as variably-shaped flesh-spicules. The recent Tetractinellid

Sponges are all inhabitants of the sea, and the genera *Geodia* and *Tethya* are well-known examples of the group. Fossil Sponges of this order are found in rocks as old as the Mountain Limestone (Carboniferous).

ORDER 5. LITHISTIDÆ.—The Lithistid Sponges have a firm resistant skeleton, wholly composed of siliceous spicules, and they have been sometimes spoken of, along with the sponges of the following order, as "Vitreous Sponges." The

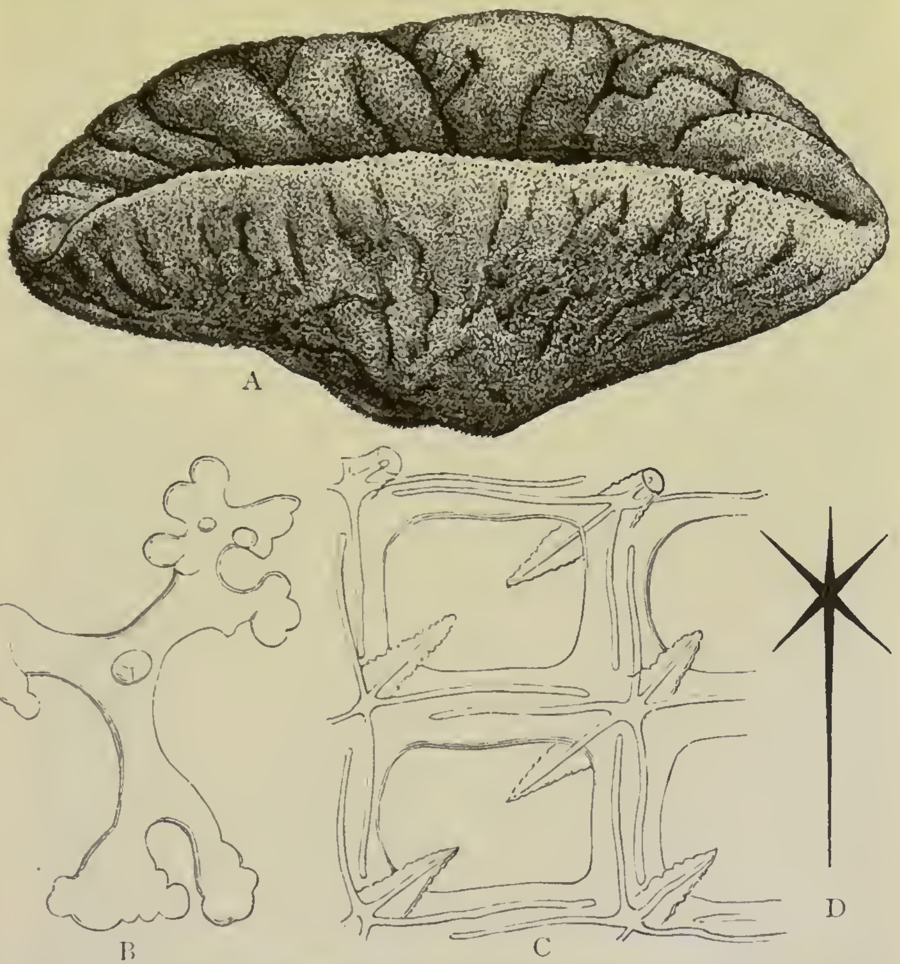


Fig. 46.—A, *Dactylocalyx pumiceus*, a Hexactinellid Sponge from the West Indies. B, A spicule of the Lithistid Sponge *Discodermia*, greatly enlarged, showing the branched ends of the spicule. C, Part of the skeleton of the Hexactinellid *Farrea occa*, greatly enlarged, showing the continuous lattice-like framework, the component spicules of which are only recognisable by their six-rayed axial canals. D, Plan of a single spicule of a Hexactinellid Sponge. (After Lütken, Sollas, and Carter.)

variably-shaped, coral-like skeleton is made up of essentially quadriradiate (sometimes irregularly branched) siliceous spicules (figs. 45, *e*, and 46, B), three of the four arms of which

are so disposed as to come together at an angle of 120°, while the fourth arm lies in a different plane to the others, and forms a cylindrical shaft from which the latter spring. The extremities of the arms of the spicules are divided into processes (fig. 45, *e*), and by the interlocking of these, contiguous spicules are united into a continuous and rigid skeleton, the meshes of which are more or less irregular and curvilinear. There may be a single terminal osculum, or numerous scattered oscula; and the soft tissues commonly contain isolated "flesh-spicules."

The Lithistid Sponges are all marine, and are inhabitants of deep water. Well-known recent genera are *Discodermia*, *Corallistes*, *M'Andrewia*, *Azorica*, and *Leiodermatium*. Numerous fossil forms of the *Lithistidæ* are known, beginning in the Silurian period.

ORDER 6. HEXACTINELLIDÆ. — In this group of the siliceous sponges, the skeleton is composed of six-armed flinty spicules, the rays of which are at right angles to each other (fig. 46, D). In the centre of each spicule are three canals cutting each other at right angles, and forming an axial six-rayed tube. In some Hexactinellid sponges, the spicules are simply united by the soft tissues. More commonly, the spicules are fused with one another by the ends of corresponding rays, or are united by means of amorphous silica, so as to form a trellis-work of rectangular or polyhedral meshes, the individual spicules of which may be only recognisable by the persistence of their axial canals (fig. 46, C). The "flesh-spicules" are fundamentally six-armed, but may give off secondary branches so as to form a rosette.

Among the living *Hexactinellidæ*, the Venus' Flower-basket (*Euplectella*) is one of the most familiar forms. In this exquisitely beautiful sponge, the skeleton-spicules are of large size, and the entire skeleton is at first flexible and soft, the spicules being free. Ultimately, the spicules become cemented together by a coating of vitreous silex, so as to form a ladder-like trellis-work. There is a single terminal osculum, provided with a porous lid; the sponge-body is rooted in the mud of the sea-bottom by a beard of long siliceous fibres; and the entire skeleton in the living state is completely concealed by a thick covering of brown sarcode. Another beautiful form is the "Bird's-nest Sponge" (*Holtenia*, fig. 47), which is anchored to the mud at the bottom of the sea by a wisp of siliceous fibres. Another very interesting Hexactinellid sponge is the *Hyalonema* or "Glass-rope Zoophyte," long supposed to be a kind of coral. In this singular type, there is a comparatively

Fig. 47.—*Holtenia Carpenteri*, a siliceous Sponge belonging to the group of the *Hexactinellidæ*. (After Sir Wyville Thomson.)

small sponge-body, which is rooted to the mud at the sea-bottom by a long rope of delicate siliceous fibres. In addition to this skein of "anchoring-fibres," there are branched spicules, which are four-armed or five-armed in the recent forms, but are hexradiate in fossil examples. Other well-known living *Hexactinellidæ* are *Aphrocallistes*, *Farrea*, *Dactylocalyx*, (fig. 46, A), &c. All the known forms are marine, and are inhabitants of deep water. Very many fossil forms of the Hexactinellid sponges are known, beginning as early as the Cambrian period.

CLASS II.—CALCISPONGIÆ.

The second class of Sponges comprise forms in which the skeleton is composed of spicules of carbonate of lime. The spicules are never, in living species, fused with one another, nor united by a horny fibre, and are in the form of simple fusiform rods, or of three-rayed (rarely four-rayed) needles.

The triradiate spicules (fig. 48, A) are the form especially

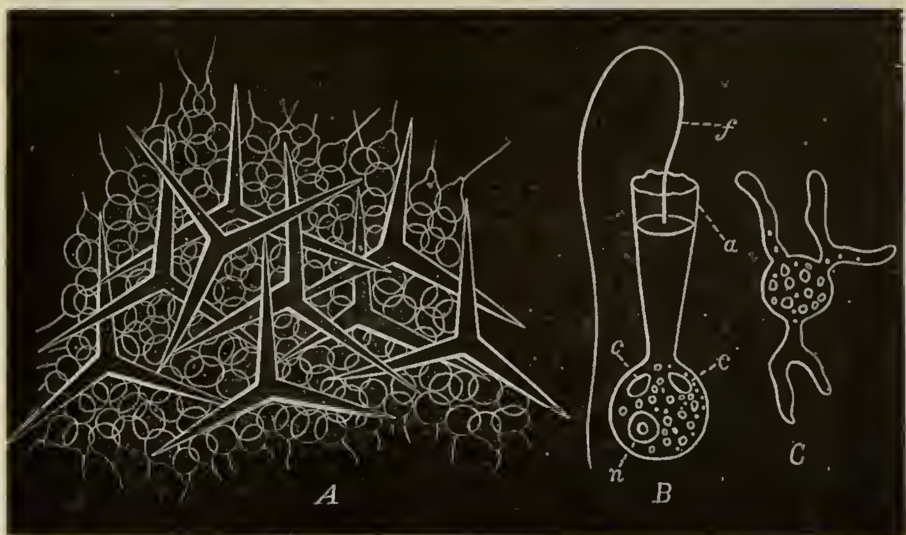


Fig. 48.—A, Portion of *Grantia*, highly magnified, showing the triradiate spicules and the sponge-cells; B, A flagellate sponge-cell of *Grantia compressa*, greatly enlarged, showing the membranous collar (*a*), the flagellum (*f*), the contractile vesicles (*c c*), and the nucleus (*n*); C, A cell of *Grantia compressa*, with the pseudopodia protruded and without the flagellum, greatly enlarged. (B and C are after Carter.)

characteristic of the *Calcispongiæ*, but two or all of the known forms of spicule may occur in a single sponge. In the group of fossil sponges, described by Zittel under the name of *Pharetrones*, the skeleton is formed by a reticulated calcareous fibre, which is "wholly composed of spicules in close approximation

to each other, and as closely interwoven together as the strands of a rope" (Hinde).

The canal-system of the *Calcispongiæ* exhibits considerable differences as regards its development and arrangement in different groups. In one series of forms (the *Ascones* of Haeckel) the sponge has the form of a simple thin-walled sac, which opens at its apex by a single osculum, and is lined throughout by flagellated cells, the wall being perforated by numerous constantly-changing pores for the admission of water (fig. 41). In these forms, therefore, there are no proper inhalant or exhalant canals. In another group (the *Sycones* of Haeckel) the sponge is sac-like, with a central cavity and terminal osculum, but with thick walls, which are traversed by numerous simple radial canals opening on the surface by "pores." The endoderm of the central chamber is not flagellated, but the radial canals are dilated into flagellated chambers. In a third group of forms (the *Leucones* of Haeckel), the general form of the Sponge is the same as in the preceding group, but the canals traversing the thick walls of the body are branched.

The living Calcareous Sponges are all of small size, and of delicate texture, and they are all inhabitants of the sea. *Grantia compressa* and *Leucandra nivea* are well-known British examples of the order.

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CŒLENTERATA.

CHAPTER VII.

THE SUB-KINGDOM CŒLENTERATA.

1. Characters of the Sub-Kingdom. 2. Divisions. 3. General Characters of the Hydrozoa. 4. Explanation of Technical Terms.

The sub-kingdom *Cœlenterata* (Frey and Leuckart) may be considered as a modern representative of the *Radiata* of Cuvier. From the *Radiata*, however, the *Echinodermata* and *Rotifera* have been removed, the entire sub-kingdom of the *Protozoa* has been taken away, and the *Polyzoa* have been relegated to a place near the *Mollusca*. Deducting these groups from the old *Radiata*, the residue, comprising most of the animals commonly known as Polypes or Zoophytes, remains to constitute the modern *Cœlenterata*.

The *Cœlenterata* may be defined as *radially-symmetrical animals, in which the mouth opens into a simple or variously divided space* ("*cœlenteric cavity*"), *which acts as an alimentary cavity, and which may or may not be divided into two portions, of which one forms a rudimentary digestive tube. The body-wall consists of two fundamental layers* ("*ectoderm*" *and* "*endoderm*"), *between which an intermediate layer* ("*mesoderm*") *is usually developed. Peculiar urticating organs, or* "*thread-cells,*" *are present. The nervous system is sometimes specialised, sometimes diffused; but no vascular organs are developed. Reproductive organs are invariably present at some period or another of life, though asexual reproduction is also very general.*

The leading feature in the Cœlenterate animals is to be found in the fact that the walls of the body enclose a cavity (fig. 49, *b*), which is concerned with the processes of digestion and circulation, and which *represents* the body-cavity of the

higher animals. Into this general cavity the mouth opens, either directly or by the intervention of a short œsophageal tube. There are, however, no proper digestive organs apart

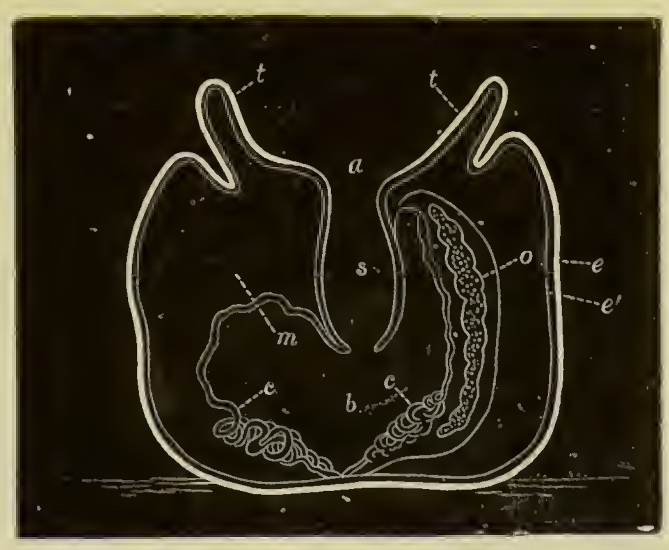

Fig. 49. — Diagrammatic vertical section of a Sea-Anemone. *a* Mouth; *s* Gullet; *b* Body-cavity; *c c* Convoluted cords ("craspeda") containing thread-cells, and forming the free edges of the mesentery (*m*); *t t* Tentacles; *o* Reproductive organ contained within the mesentery. The ectoderm (*e*) is indicated by the broad external line, the endoderm (*e'*) by the thin line and the space between that and the ectoderm.

from this cavity, nor are definite circulatory organs developed. The fluid filling the general body-cavity corresponds, in fact, to the blood of the higher animals, and its circulation is carried on by the ciliated lining of the cavity. The general cavity included within the walls of the body may therefore be appropriately spoken of as the "gastro-vascular space."

The mouth of the *Cœlenterata* is surrounded by hollow or solid, tactile or prehensile filaments, which are known as the "tentacles." These organs are arranged in a "radiate" manner; though traces of bilateral symmetry are by no means wholly wanting among the Cœlenterates. They are absent in *Protohydra* and *Microhydra*, and in the sexless zoöids of the *Alcyonaria;* and they may be completely retractile or only capable of being shortened.

As regards the fundamental tissues of the *Cœlenterata*, there exist two primary membranes, an external and internal, which are known respectively as the "ectoderm" and "endoderm" (fig. 49, *e* and *e'*). The ectoderm covers the whole outer surface of the body, and also lines the œsophagus, when this is present. The endoderm covers the entire inner surface of the body, the cavities of the tentacles, and the outside of the

gullet (when this is present). The ectoderm and endoderm correspond with the primitive serous and mucous layers ("epiblast" and "hypoblast") of the germinal area, and become differentiated in opposite directions, the ectoderm growing from within outwards, and the endoderm from without inwards. Each is primitively cellular, but the inner portions of both may become specialised so as to give rise to different tissues. Between the ectoderm and endoderm there is, typically, developed a third layer or "mesoderm," which is essentially of the nature of connective tissue.

In the higher Cœlenterates, such as the Sea-anemones, the *ectoderm* is composed of exceedingly long and narrow nucleated cells, placed at right angles to the surface (fig. 50, A, *ec*), and having their free outer ends fur-

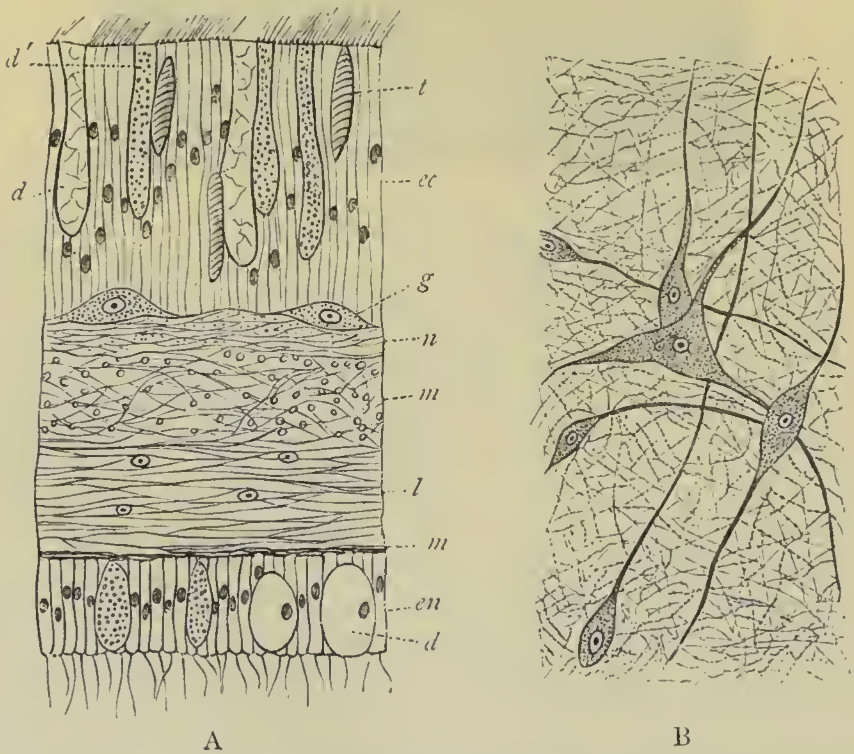

Fig. 50.—Histology of *Cœlenterata*. A, Vertical section of the oral disc of a Sea-Anemone, greatly enlarged (slightly altered after O. and R. Hertwig): *ec* Ectoderm, composed of long epithelial cells, along with thread-cells (*t*), and gland-cells (*d* and *d'*); *en* Endoderm, with gland-cells (*d*); *l* Mesoderm; *m m* Muscular layers; *n* Nervous layer; *g* One of the large ganglion-cells. B, Nervous layer, consisting of delicate fibres and large nerve-cells, in a Sea-Anemone—greatly enlarged. (After O. and R. Hertwig.)

nished with cilia or flagella. Interspersed among the ordinary ectodermal cells are various special cells—viz., the "thread-cells" (fig. 50, A, *t*), large glandular cells of different kinds, and peculiar "sense-cells."

The *endoderm* (fig. 50, A, *en*) consists of cells, similar in most respects

to those of the ectoderm, but shorter. The inner ends of the endodermal cells are ciliated, or are furnished with flagella, and intermixed among them are numerous glandular cells.

The *mesoderm* (fig. 50, A, *l*) consists essentially of connective tissue, and forms a kind of framework ("supporting lamina"), which accurately corresponds with the form of the body.

Both the ectoderm and the endoderm may undergo partial differentiation into muscular and nervous elements. The muscles have the form of long fibrils, some of which have a longitudinal and others a circular direction. They are developed primitively from both the inner side of the ectoderm and the outer side of the endoderm (fig. 50, A, *m m*); but they often come ultimately to lie in the mesoderm. A layer of a nervous nature is developed at the inner side of the ectoderm (fig. 50, A, *n*), consisting of nerve-fibres and large ganglion-cells. The cells (fig. 50, B) are of large size, and give off long delicate fibres, but they are simply diffused, and are not aggregated into definite ganglia. In some forms, however, nerve-cords have been recognised. Similar nervous elements to those found in the ectoderm may be likewise developed, though more sparingly, in the endoderm.

In connection with the integument of the *Cœlenterata*, the organs termed "thread-cells" ("cnidæ," or "nematocysts") must be noticed. These are peculiar cellular bodies (fig. 51),

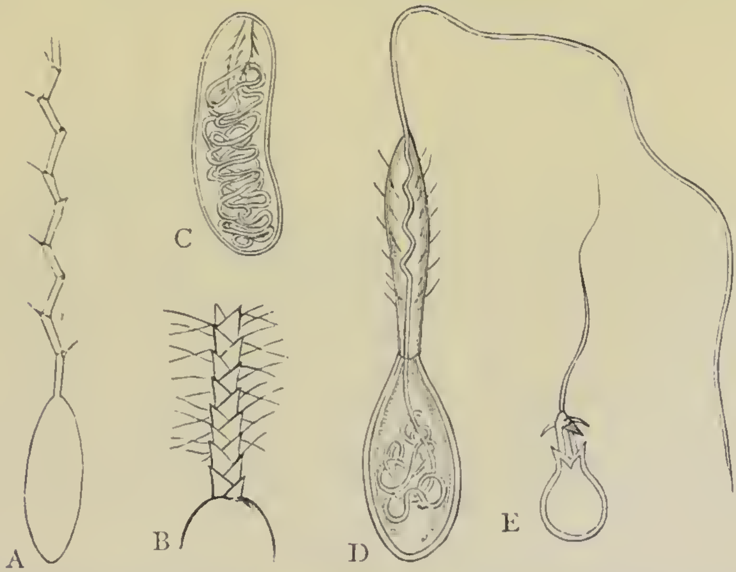

Fig. 51.—Thread-cells of Cœlenterata, greatly magnified. A and B, The thread-cell of *Caryophyllia Smithii*, in the everted condition, and in two varieties; C and D, The thread-cell of *Corallimorphus profundus*, in a quiescent and active condition, enlarged about 500 times; E, The thread-cell of *Hydra*, in an everted condition. (After Gosse and Moseley.)

of various shapes, which are used in killing the prey of the animal, and also as weapons of offence and defence, and which communicate to many members of the sub-kingdom (*e.g.*, the Sea-blubbers) their well-known power of stinging. The thread-

cells have the form of capsules filled with fluid, and having coiled up in their interior a longer or shorter thread. Each capsule is developed within a cell, which carries a delicate sensitive process ("cnidocil"). When this process is touched, the cell bursts and the thread is thrown out of the sac to its full length, piercing any soft substance with which it may come in contact. The thread is often barbed or serrated, and the fluid contained within the capsule probably has some poisonous action. Thread-cells of various forms are exceedingly characteristic of the Cœlenterates, but analogous organs exist in other animals (*e.g.*, in the *Infusoria*, the Planarian worms, some Annelides, &c.) They are specially developed in the ectoderm (fig. 50, A, *t*), and are, as a rule, especially abundant in the tentacles. In one group of the Cœlenterates—viz., the *Ctenophora*—thread-cells are rarely present, but their place is taken by analogous structures ("fixing-cells"). Besides the thread-cells, the tentacles of some Hydroids are furnished with rigid hair-like processes, which are probably tactile in function, and which are known as "palpocils."

The *Cœlenterata* are divided into two classes, termed respectively the *Hydrozoa* and the *Actinozoa*.

Class I. Hydrozoa.

The *Hydrozoa* are defined as *Cœlenterata in which the walls of the body enclose a simple undivided cavity* (*the "cœlenteric cavity"*), *which acts both as a body-cavity and a digestive cavity. An œsophageal tube is not developed; but the upper end of the alimentary tract may be prolonged into radiating canals united by a peripheral ring. The reproductive organs are external buds, and are often developed in specially modified zoöids* (fig. 52).

It follows from the above, that, since there is but a single internal cavity, the body of a *Hydrozoön* on transverse section appears as a single tube, the walls of which are formed by the limits of the general parietes of the body.

The *Hydrozoa* are all aquatic, and the great majority are marine. The class includes both simple and composite organisms, the most familiar examples being the common Fresh-water Polypes (*Hydra*), the Sea-firs (*Sertularida*), the Jelly-fishes (*Medusæ*), and the Portuguese man-of-war (*Physalia*).

Owing to the great difficulty which is ordinarily experienced by the student in mastering the details of this class of animals, it has been thought advisable to introduce here a short explanation of some of the technical terms which are in more general use in describing these organisms.

GENERAL TERMINOLOGY OF THE HYDROZOA.

Individual.—We have already seen (*see* Introduction) that the term "individual," in its zoological sense, must be restricted to "the entire result of the development of a single fertilised ovum," and that in this sense an individual may either be simple, like an *Amœba*, or may be composite, like

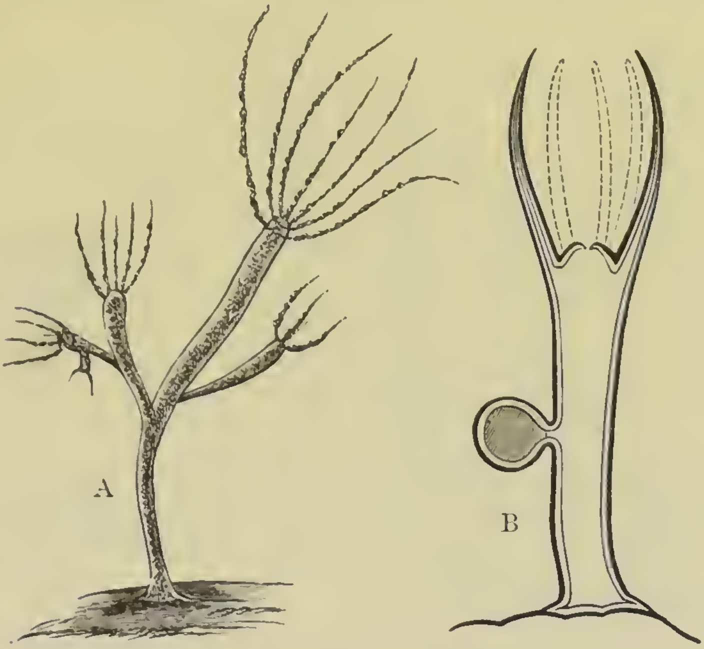

Fig. 52.—A, The common Hydra (*Hydra vulgaris*), carrying young *Hydræ* which it has produced by budding, considerably magnified (after Hincks). B, Diagrammatic section of the *Hydra*, showing the mouth surrounded by the tentacles, and the disc of attachment; the dark and light lines indicate the two layers of the integument, and on one side of the body is shown a single large egg.

many Infusorians (*e.g.*, *Epistylis*). If all the parts composing an individual remain mutually connected, its development is said to be "continuous"; but if any of these parts become separated as independent beings, the case becomes one of "discontinuous" development. We have seen, also, that however long zoöidal multiplication may go on, there ultimately arrives in the history of every individual a period at which sexual reproduction must be called in to ensure the perpetuation of the species throughout time. This truth is expressed by Steenstrup's celebrated law of the "alternation of generations."

Amongst the *Hydrozoa*, the individual may be either simple or compound, and the development may be either continuous or discontinuous, the following terms being employed to denote the phenomena which occur.

Hydrosoma.—This is the term which is employed to designate the entire body of a *Hydrozoön*, whether it be simple, as in the *Hydra*, or composite, as in a *Sertularian*.

Polypite.—The alimentary region of a *Hydrozoön* is called a "polypite"; the term "polype" being now restricted to the same region in the *Actinozoa*. In the simple *Hydrozoa* the entire organism may be called a "polypite"; but the term is more appropriately applied to the separate nutritive

factors which together make up a compound *Hydrozoön*. By Professor Allman the term "hydranth" is used in preference to "polypite."

Distal and Proximal.—These are terms applied to different extremities of the hydrosoma. It is found that one extremity grows more quickly than the other, and to this free-growing end—at which the mouth is usually situated—the term "distal" is applied. To the more slowly growing end of the hydrosoma—which is at the same time usually the fixed end—the term "proximal" is applied. These terms may be used either in relation to a single polypite in the compound *Hydrozoa*, or to the entire hydrosoma, whether simple or compound.

Hydrorhiza.—This term is applied to that portion of the proximal end of a Hydroid colony by which it is attached to some foreign body.

Cœnosarc.—This is the term which is employed to designate the common trunk, which unites the separate polypites of any compound *Hydrozoön* into a single organic whole.

Polypary.—The term "polypary" or "polypidom" is applied to the horny or chitinous outer covering or envelope with which many of the *Hydrozoa* are furnished. These terms have also not uncommonly been applied to the very similar structures produced by the much more highly organised Sea-mats and their allies (*Polyzoa*), but it is better to restrict their use entirely to the *Hydrozoa*. By Professor Allman the term "perisarc" is given to the chitinous investment by which the soft parts of the *Hydrozoa* are often protected, while other writers use the term "periderm."

Zoöids.—In continuous development, the partially independent beings which are produced by gemmation or fission from the primitive organism, to which they remain permanently attached, are termed "zoöids." In other words, the "zoöids" are the more or less individualised members of which the Hydroid colony is made up.

In discontinuous development, where certain portions of the "individual" are separated as completely independent beings, these detached portions are likewise termed "zoöids"; that which is first formed being distinguished as the "producing zoöid," whilst that which separates from it is known as the "produced zoöid." In a great number of *Hydrozoa* there exist two distinct sets of zoöids, one of which is destined for the nutrition of the colony, and has nothing to do with generation, whilst the functions of the other, as far as the colony is concerned, are wholly reproductive. For *the whole assemblage of the nutritive zoöids of a Hydrozoön* Professor Allman has proposed the term "trophosome," applying the term "gonosome" to *the entire assemblage of the reproductive zoöids*. In such *Hydrozoa*, therefore, as possess these two distinct sets of zoöids, the "individual," zoologically speaking, is composed of a trophosome and a gonosome. It follows from this that neither the trophosome nor the gonosome, however apparently independent, and though endowed with intrinsic powers of nutrition and locomotion, can be looked upon as an "individual," in the scientific sense of this term. As a rule, the zoöids of the trophosome are all like one another, or are "homomorphic"; but there are some cases (as in *Hydractinia*, and in the nematophores of the *Plumularidæ*) in which some of the zoöids of the trophosome are unlike the others. The zoöids of the gonosome, on the other hand, are normally unlike, or are "heteromorphic," consisting of two or three different sets of zoöids, each with its special duty in the generative functions of the Hydroid colony.

Gonophores.—The general name of "gonophores" is given to the external buds in which the reproductive elements are produced in the *Hydrozoa*. Except in *Hydra*, the gonophores can be more or less clearly shown to be modified zoöids or polypites (fig. 53). Usually the gonophore consists of

an external investment, which encloses a fixed generative sac or a free sexual zoöid (gonozoöid). In the highest stage of development, the sexual zoöid is ultimately detached from the parent colony ("trophosome") to lead an independent existence, when it constitutes a *Medusa*, or Jelly-fish

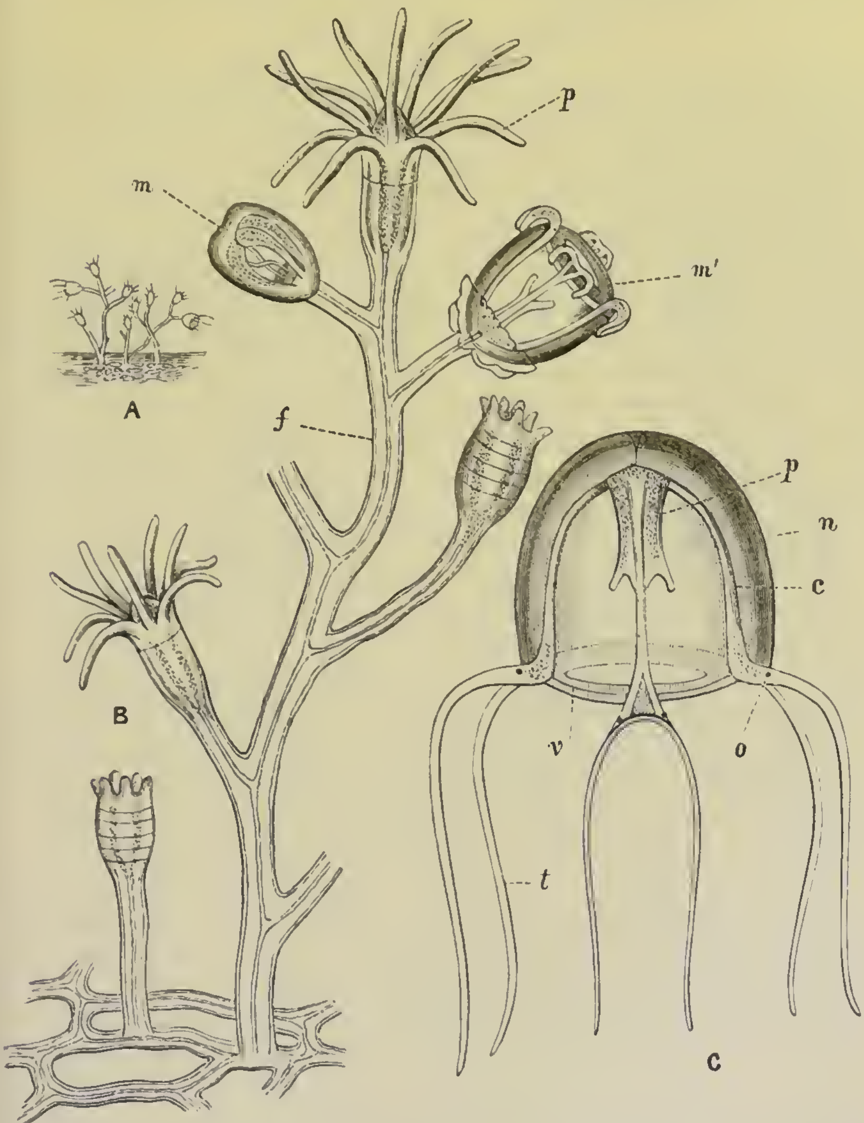

Fig. 53.—A, Part of the colony of *Bougainvillea muscus*, of the natural size. B, Part of the same enlarged: *p* A polypite fully expanded; *m* An incompletely developed medusiform bud; *m′* A more completely developed medusiform bud; *f* Cœnosarc with its investing periderm and central canal. C, A free medusiform gonophore of the same: *n* Gonocalyx; *p* Manubrium; *c* One of the radiating gastro-vascular canals; *o* Ocellus; *v* Velum; *t* Tentacle. (After Allman.)

(fig. 53, C). In other cases, the generative bud assumes the form of a *Medusa*, but is not set free from the parent, in which case it is known as a "medusiform gonophore."

CHAPTER VIII.

DIVISIONS OF THE HYDROZOA.

SUB-CLASS HYDROIDA.*

THE *Hydrozoa* are divided into six sub-classes—viz., the *Hydroida*, the *Siphonophora*, the *Lucernarida*, the *Graptolitoidea*, the *Hydrocorallinæ*, and the *Stromatoporoidea*.

SUB-CLASS I. HYDROIDA.—This sub-class comprises *Hydrozoa in which the hydrosoma consists typically of numerous simple polypites united by a branched cœnosarc, and forming a more or less plant-like colony attached to foreign bodies by an adherent base* ("*hydrorhiza*"). *Very commonly the colony develops a hard outer layer or* "*polypary.*" *Reproduction takes place by fixed generative buds* (*usually medusoid in structure*), *or by the development of free medusiform gonophores. In some cases the hydrosoma is simple, and may either resemble a single polypite of one of the colonial forms* (*as in Hydra*), *or may be similar to a medusiform gonophore* (*as in the Trachymedusæ*).

The "Hydroid Zoophytes" may be divided into five orders —viz., the *Hydrida*, the *Corynida*, the *Thecaphora*, the *Thecomedusæ*, and the *Trachymedusæ*.

ORDER I. HYDRIDA (*Eleutheroblastica*, Allman; *Gymnochroa*, Hincks).—This order comprises those *Hydrozoa whose* "*hydrosoma*" *consists of a single locomotive polypite, with tentacles and* "*hydrorhiza,*" *and with reproductive organs which appear as simple external processes of the body-wall. The hydrorhiza is discoid, and no hard cuticular layer is at any time developed.*

The order *Hydrida* comprises a single genus† only (*Hydra*), including the various species of "Fresh-water Polypes," as they are often called. The common *Hydra* (fig. 52, A) is found abundantly in this country, and consists of a tubular cylindrical body, the "proximal" extremity of which is expanded into an adherent disc or foot—the "hydrorhiza"—by means of which the animal can attach itself to some foreign body. It possesses, however, the power of detaching the hydrorhiza

* For full details as to the morphology and physiology of the Hydroid Zoophytes, the student should refer to the magnificent 'Monograph of the Gymnoblastic Hydroids,' by Professor Allman (Ray Society). The student should also consult the excellent 'History of British Hydroid Zoophytes,' by the Rev. Thomas Hincks.

† If the *Protohydra* of Greeff be a mature form, it also belongs to this order. It differs from *Hydra* in having no tentacles. In *Microhydra* both tentacles and the basal disc are wanting.

at will, and thus of changing its place. At the opposite or "distal" extremity of the body is placed the mouth, surrounded by a circlet of tentacles, which arise a little distance below the margin of the oral aperture. The tentacles vary in number from five to twelve or more, and they vary considerably in length in different species, being much shorter than the body in the *Hydra viridis* (fig. 54), but being extremely long and filamentous in *Hydra oligactis*. They are highly extensile and contractile, and serve as organs of prehension, being capable of retraction till they appear as nothing more than so many warts or tubercles, and of being extended to a length which is in some species longer than the body itself. Each consists of a prolongation of both ectoderm and endoderm, enclosing a diverticulum of the somatic cavity, and they are abundantly furnished with thread-cells. The cylindrical hydrosoma (fig. 52, B), is excavated into a single large cavity, lined by the endoderm, and communicating with the exterior by the mouth. This—the "somatic cavity"—is the sole digestive cavity with which the *Hydra* is provided, the indigestible portions of the food being rejected by the mouth. The ectodermal cells give off at their inner ends branched filaments which form a layer of "neuro-muscular" fibres internal to the ectoderm. In *Hydra viridis*, also, the ectoderm contains chlorophyll.

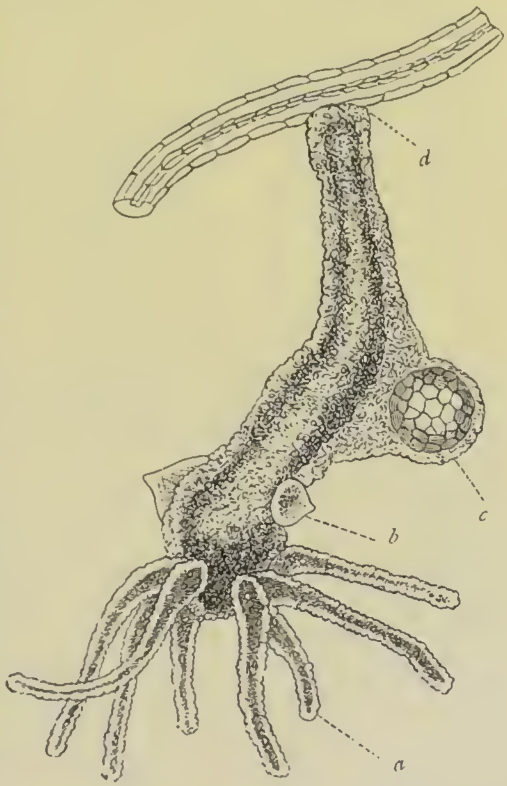

Fig. 54.—The Green Fresh-water Polype (*Hydra viridis*), suspended head-downwards from a piece of a stem of an aquatic plant, enlarged. *a* One of the tentacles; *b* Testis or spermarium, with spermatozoa in its interior; *c* A single large ovum, protruding from the side of the body; *d* Disc of attachment ("hydrorhiza").

The *Hydra* possesses a most extraordinary power of resisting mutilation, and of multiplying artificially when mechanically divided. Into however many pieces a *Hydra* may be

divided, each and all of these will be developed gradually into a new and perfect polypite. The remarkable experiments of Trembley upon this subject are well known, and have been often repeated, but space will not permit further notice of them here. Reproduction is effected in the *Hydra* both asexually by gemmation, and sexually—the former process being followed in summer, and the latter towards the commencement of winter, few individuals surviving this season. In the first method the *Hydra* (fig. 52, A) throws out one or more buds, generally from near its proximal extremity. These buds at first consist simply of a tubular prolongation of the ectoderm and endoderm, enclosing a cæcal diverticulum of the body-cavity; but a mouth and tentacles are soon developed, when the new being is usually detached as a perfect independent *Hydra*. The *Hydræ* thus produced throw out fresh buds, often before they are detached from the parent organism, and in this way reproduction is rapidly carried on.

In the second or sexual mode of reproduction, ova and spermatozoa are produced in outward processes of the body-wall (fig. 54). The spermatozoa are developed in little conical elevations, which are produced near the bases of the tentacles, and the ova are enclosed in sacs of much greater size, situated nearer the fixed or proximal extremity of the animal. Ordinarily there is but one of these sacs, containing a single ovum, but sometimes there are two. When mature, the ovum is expelled through the body-wall, and is fecundated by the spermatozoa, which are simultaneously liberated. The primitive body-cavity of the non-ciliated embryo is ultimately placed in communication with the outer world by the formation of the mouth, which is produced directly as an opening in the walls of the body, and not by invagination of the ectoderm.

ORDER II. CORYNIDA (*Gymnoblastica*, Allman; *Athecata*, Hincks). — The order *Corynida* comprises those *Hydrozoa whose hydrosoma is fixed by a hydrorhiza, and consists either of a single polypite, or of several united by a cœnosarc, which usually develops a firm outer layer or "polypary." No "hydrothecæ" are present. "The reproductive organs are in the form of gonophores, which vary much in structure, and arise from the sides of the polypites, from the cœnosarc, or from gonoblastidia"* (Greene).

The hydrosoma of the *Corynida* may consist of a single polypite, as in *Coryomorpha* and *Vorticlava*, or it may be composed of several united by a cœnosarc, as in *Cordylophora* (fig. 55, *a*). The order is entirely confined to the sea, with the single exception of *Cordylophora*, which inhabits fresh water.

In *Tubularia* and its allies the organism is protected by a well-developed external chitinous envelope or "polypary"; but in the other genera belonging to the order, the polypary is either rudimentary or is entirely absent. The polypary of the

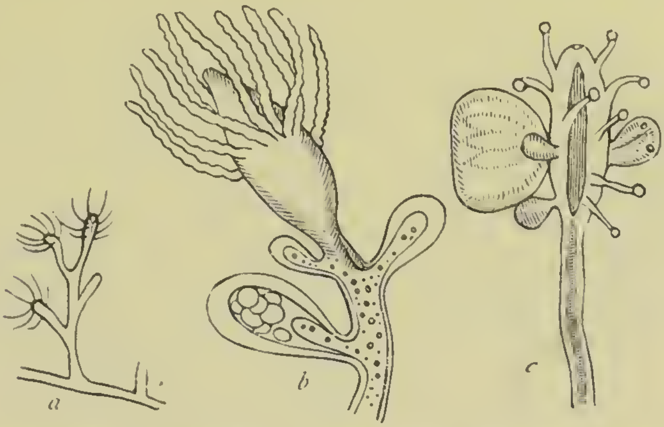

Fig. 55.—Morphology of Corynida. *a* Fragment of *Cordylophora lacustris*, slightly enlarged; *b* Fragment of the same considerably enlarged, showing a polypite and three gonophores in different stages of growth, the largest containing ova; *c* Portion of *Syncoryne Sarsii* with medusiform zoöids budding from between the tentacles.

Corynida, when present, is readily distinguished from that of the *Sertularida*, by the fact that in the former it extends only to the bases of the polypites; whereas in the latter it expands to form little cups for the reception of the polypites, these cups being called "hydrothecæ." Owing to the fact that neither the polypites nor the generative buds of the *Corynida* are enclosed in a chitinous investment, the name of "Gymnoblastic Hydroids" is applied to them by Professor Allman.

As regards the reproductive process in the *Corynida*, the reproductive elements are developed in distinct buds or sacs, which are external processes of the body-wall, and have been aptly termed "gonophores" by Professor Allman. Great variations exist in the form and development of these generative buds, and an examination of these leads us to some of the most singular phenomena in the entire animal kingdom. In some species of *Hydractinia* and *Coryne*, the generative buds or "gonophores" exist in their simplest form—namely, as sac-like protuberances of the endoderm and ectoderm, enclosing a diverticulum of the somatic cavity. In this form they are attached to the "trophosome" by a short stalk, and they are termed "sporosacs" (fig. 56). They are exactly like the buds which we have already seen to exist in the *Hydra*, with this difference, that they are not themselves developed

into fresh polypites, but are simply receptacles in which the essential elements of generation—the ova and spermatozoa—are prepared, by the union of which the young *Corynid* is produced. The sporosac is almost invariably permanently attached to the trophosome, the only known exception being in *Dicoryne*, in which the sporosac, previous to the discharge of its ova, liberates itself from its outer investment, and swims about freely as an independent ciliated organism.

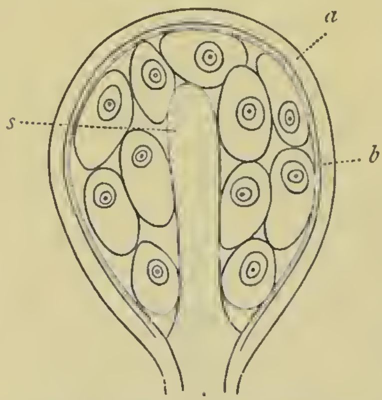

Fig. 56.—Sporosac of *Hydractinia echinata* (after Allman). *a* Outer wall of the sac; *b* Inner wall of the sac; *s* Column developed from the floor of the sporosac, and extending into its cavity. This is termed the "spadix"; it contains a prolongation from the cœnosarcal canal, and the ova are developed around it.

In *Cordylophora* (fig. 57, *b*) a further advance in structure is perceptible. The gonophore now consists of a closed sac, from the roof of which depends a hollow process or peduncle—the "manubrium"—which gives off a system of tubes which run in the walls of the sac. For reasons which will be immediately evident, the gonophore in this case is said to have a "disguised" medusoid structure (fig. 57, *b*).

In certain *Corynida*, however, we meet with a still higher form of structure, the gonophores being now said to be "medusoid." In these cases the generative bud is primitively a simple sac—such as the "sporosac"—but ultimately develops itself into a much

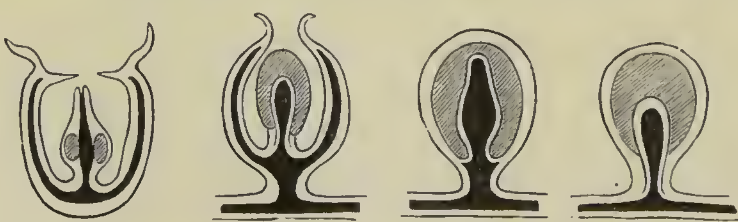

Fig. 57.—Diagrams of the gonophores of Hydrozoa. *a* Sporosac; *b* Disguised medusoid; *c* Attached medusiform gonophore; *d* Free medusiform gonophore. The cross shading indicates the reproductive organs, ovaria or spermaria. The part completely black indicates the cavity of the manubrium and the gonocalycine canals.

more complicated structure. The gonophore (figs. 53, C, and 58) is now found to be composed of a bell-shaped disc, termed the "gonocalyx," which is attached by its base to the parent organism (the trophosome), and has its cavity

turned outwards. From the roof of the gonocalyx, like the clapper of a bell, there depends a peduncle or "manubrium," which contains a process of the somatic cavity, and is in reality a modified polypite. The manubrium gives out at its fixed or proximal end four, six, or eight prolongations of its cavity, in the form of radiating lateral tubes which run to the margin of the bell, where they communicate with one another by means of a single circular canal which surrounds the mouth of the bell. This system of tubes constitutes what is known as the system of the "gastro-vascular" or "gonocalycine" canals. The gonophore, thus constituted, may remain permanently attached to the parent organism, as in *Tubularia indivisa* (fig. 57, *c*); but in other cases still further changes ensue. In the higher forms of development (fig. 58) the manubrium acquires a mouth at its free or distal extremity, and the gonocalyx becomes detached from the parent.

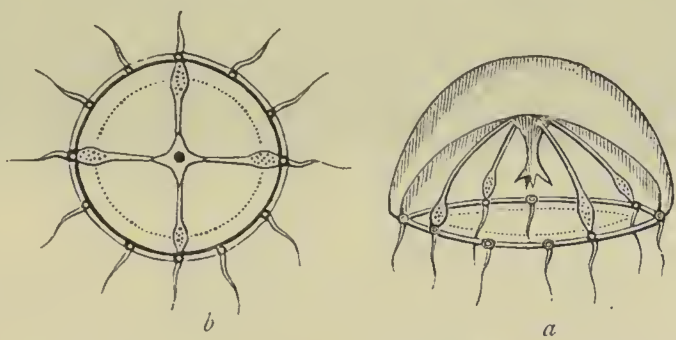

Fig. 58.—Structure of a free medusiform gonophore. *a* Medusoid (*Thaumantias*) seen in profile, showing the central polypite, the radiating and circular gonocalycine canals, the marginal vesicles and tentacles, and the reproductive organs; *b* The same viewed from below. The dotted line indicates the margin of the velum.

The gonophore is now free, and behaves in every respect as an independent being. The gonocalyx is provided with marginal tentacles, and with an inward prolongation from its margin, which partially closes the mouth of the bell, and is termed the "veil" or "velum." By the contractions of the gonocalyx, which now serves as a natatorial organ, the gonophore is propelled through the water. The manubrium, with the shape, assumes the functions of a polypite, and its cavity takes upon itself the office of a digestive sac. Growth is rapid, and the gonophore may attain a comparatively gigantic size, being now absolutely identical with one of those organisms which are commonly called "jelly-fishes," and are technically known as *Medusæ* (fig. 59). In fact, as we shall afterwards see, many of the so-called *gymnophthalmate Medusæ*, originally described

as a distinct order of free-swimming Hydrozoa, are in truth merely the liberated generative buds, or "medusiform gonophores," of the permanently rooted *Hydroids*. Finally, the

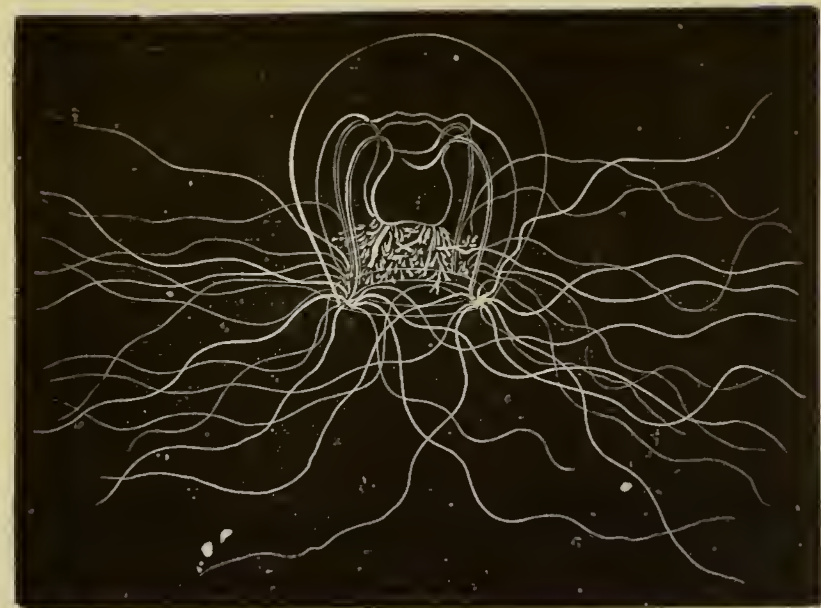

Fig. 59.—Free-swimming medusiform gonophore of *Bougainvillea superciliaris*, a fixed Hydroid. Enlarged. (After A. Agassiz.)

essential generative elements—the ova and spermatozoa—are developed in the walls of the manubrial sac, between its endoderm and ectoderm, and embryos are produced. These embryos, however, instead of resembling the organism which immediately gave them birth, develop themselves into the fixed *Corynid* from which the gonophore was produced, thus completing the cycle.

The swimming-bell of the medusiform gonophore is believed to be formed by a great development of an inter-tentacular web, such as is sometimes present, in a rudimentary form, in the nutritive zoöids. Sometimes the medusoid becomes quiescent towards the close of its existence, and the swimming-bell becomes reversed or atrophied. Lastly, in *Clavatella*, the sexual zoöid, though free and locomotive, is not provided with a swimming-bell, but creeps about by means of suctorial discs developed on branches of the tentacles.

As we have seen, the generative buds of the *Corynida* may exist in the following chief forms: 1. As "sporosacs," or simple closed sacs, consisting of ectoderm and endoderm, with a central cavity in which ova and spermatozoa are produced. 2. As "disguised medusoids," in which there is a central

manubrial process and a rudimentary system of gonocalycine canals; but the gonocalyx remains closed. 3. As complete medusoids, which have a central manubrium, a complete system of gonocalycine canals, and an open gonocalyx; but which never become detached. 4. As perfect medusiform gonophores (fig. 59) which are detached, and lead an independent existence for a time, until the generative elements are matured. In whichever of these forms the gonophore may be present, the place of its origin from the trophosome may vary in different species of the order. 1. They may arise from the sides of the polypites, as in *Coryne* and *Stauridia;* 2. They may be produced from the cœnosarc, as in *Cordylophora:* 3. They may be produced upon certain special processes, which are termed "gonoblastidia," as in *Hydractinia* and *Dicoryne.* These gonoblastidia (fig. 60, *g*) are processes from

Fig. 60.—Diagram of sporosacs supported upon a gonoblastidion (or blastostyle). *a* Chitinous investment (periderm) of the colony; *b* Ectoderm; *c* Endoderm; *p* Polypite; *g* Gonoblastidion, or columniform zoöid, carrying sporosacs (*s s*) with ova in their interior. (Altered from Allman.)

the body-wall or cœnosarc, which closely resemble true polypites in form, but differ from them in being usually devoid of a mouth, and in having shorter tentacles. They are, in truth, atrophied or undeveloped polypites.

The gonoblastidia are the "blastostyles" of Prof. Allman,

and are usually columniform in shape. They may carry sporosacs, or medusoid gonophores; and they may be naked, or, in other orders, they may be protected within a chitinous receptacle or "gonangium."

As regards the development of the *Corynida*, the embryo is very generally, though not always, what is known as a "planula," — that is to say, a solid, two-layered locomotive embryo, with the external surface covered with cilia (fig. 61). In one form of the *Corynida*, however, the embryo leaves the gonophore as a free and locomotive polypite, and in another it is non-ciliated and amœboid. The two layers of cells which compose the planula correspond with the ectoderm and endoderm of the adult animal. In the process of development, a central cavity is formed in the planula, which corresponds with the "gastro-vascular" or "cœlenteric" space of the adult, and this is placed in communication with the exterior by the formation by absorption of a primitive mouth-opening at one pole, the embryo becoming thus converted into what Haeckel termed a "gastrula." By fixation of the "gastrula" at its hinder extremity to some foreign object, and by the formation of tentacles round the mouth-opening at the other extremity, a hydraform polypite is at once produced, which (if not belonging to one of the simple forms) proceeds to develop the composite adult by a process of gemmation. In this process in the *Corynida* (as also in the *Sertularida* and *Campanularida*) the new polypites are developed at or near the distal end of the hydrosoma, the distal polypites being thus the youngest; whereas the reverse of this obtains amongst the Oceanic *Hydrozoa*.

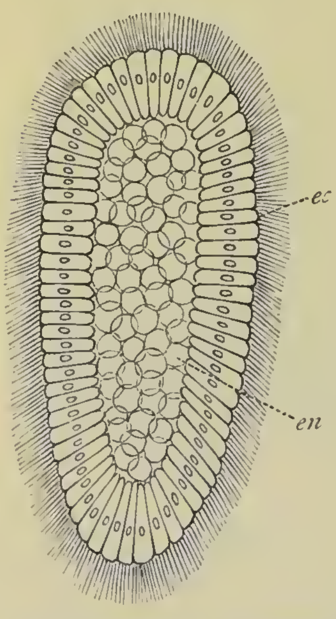

Fig. 61.—Planula of a Cœlenterate animal, showing the ectodermal and endodermal cells and the ciliated surface. Greatly magnified.

The subject of the reproduction of the *Corynida* having been treated at some length, so as to apply to the remaining *Hydroida*, we shall now give a brief description of the leading types of structure exhibited by the order.

Eudendrium, a genus of the *Corynida*, which is not uncommonly found attached to submarine objects, usually in tolerably deep water, may be taken as a good example of the fixed and composite division of the order. The hydrosoma consists of numerous polypites, united by a cœnosarc, which is more or less branched, and is defended by a horny tubular polypary. The polypites are borne at the ends of the branches and branchlets, and are not contained in "hydrothecæ," the polypary ending abruptly at their bases. The polypites are non-retractile, of a reddish colour, and

provided with about twenty tentacles, arranged round the mouth in a single row. *Tubularia* (fig. 62) is very similar to *Eudendrium*, but the hydrosoma is either undivided or is very slightly branched. The hydrosoma consists of clustered horny tubes, of a straw colour, and not unlike straws to look at; hence the common name of pipe-coralline given to this zoophyte. Each tube is filled with a soft, semi-fluid, reddish cœnosarc, and gives exit at its distal extremity to a single polypite. The polypites are bright red in colour, and are not retractile within their tubes, the horny polypary extending only to their bases. The polypites are somewhat conical in shape, the mouth being placed at the apex of the cone, and they are furnished with two sets of tentacles. One set consists of numerous short tentacles placed directly round the mouth; the other is composed of from thirty to forty tentacles of much greater length, arising from the polypite about its middle or near the base. Near the insertion of these tentacles the generative buds are produced at proper seasons. The generative buds remain permanently attached, but each is furnished with a swimming-bell, in which canals are present. The manubrium is destitute of a mouth, and "the swimming-bell is converted into a nursery in which the embryo passes through the later stages of its development" (Hincks).

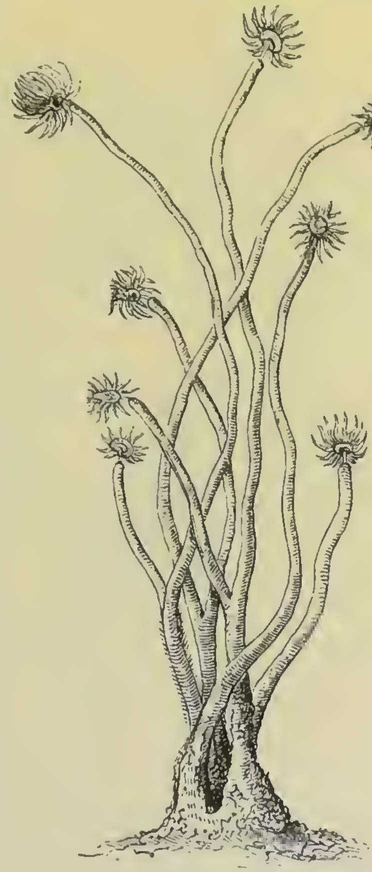

Fig. 62. — Corynida. Fragment of *Tubularia indivisa*, natural size.

Coryomorpha nutans may be taken to represent those *Corynida* in which there is no polypary and the hydrosoma is simple. It is about four inches in length, and is fixed by filamentous roots to the sand at the bottom of the sea. It consists of a single whitish polypite, striped with pink, and terminating upwards in a spear-shaped head, round the thickest part of which is a circlet of from forty to more than one hundred long white tentacles. Above these comes a series of long, branching gonoblastidia, bearing gonophores, and succeeded by a second shorter set of tentacles which surround the mouth. The gonophores become ultimately detached as free-swimming medusoids.

Another remarkable example of the *Corynida* is *Hydractinia* (fig. 63). In this genus the polypites are gregarious, and the polypary forms a horny crust which spreads over shells and other foreign bodies. The tentacles of the nutritive zoöids form a single sub-alternate series. The generative buds are produced upon imperfect, non-tentaculate polypites, and are mere sac-shaped protuberances, enclosing diverticula from the body-cavity, but not detached from the parent organism. Besides the ordinary polypites, the cœnosarc carries modified polypites in the form of long spirally-coiled filaments, which have clusters of thread-cells at their free extremity.

ORDER III. THECAPHORA (= *Calyptoblastica*, Allman).—This order comprises *Hydrozoa* in which *the hydrosoma is fixed, and consists of a more or less plant-like colony, composed of*

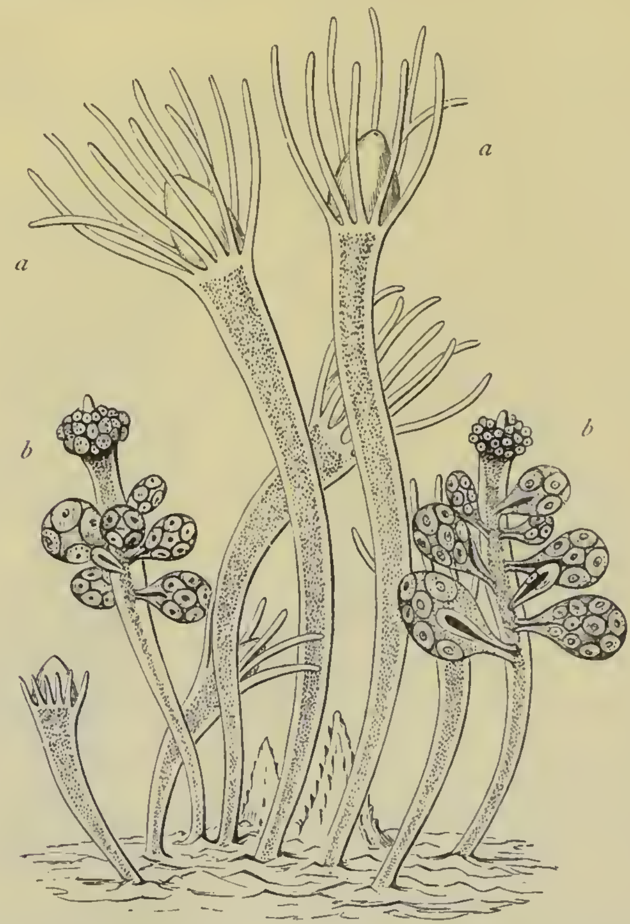

Fig. 63.—Group of zoöids of *Hydractinia echinata*, enlarged. (After Hincks.) *a a* Nutritive zoöids; *b b* Generative zoöids, carrying sacs filled with ova.

numerous polypites united by a cœnosarc. A firm outer layer or "periderm" is developed, which not only invests the cœnosarc, but is also prolonged into cup-like receptacles ("hydrothecæ"), within which the individual polypites are contained.

The *Thecaphora* are all inhabitants of the sea, and may be divided into the two sub-orders of the Sertularians and Campanularians. They resemble the *Corynida* in becoming permanently fixed after their embryonic condition by a hydrorhiza, which is developed from the proximal end of the cœnosarc; but they differ in the fact that the polypites are invariably protected by "hydrothecæ," or little cup-like expansions of the

polypary (fig. 64, C); whilst the hydrosoma is in all cases composed of more than a single polypite. The mouth of the hydrotheca is often furnished with an operculum or valve for

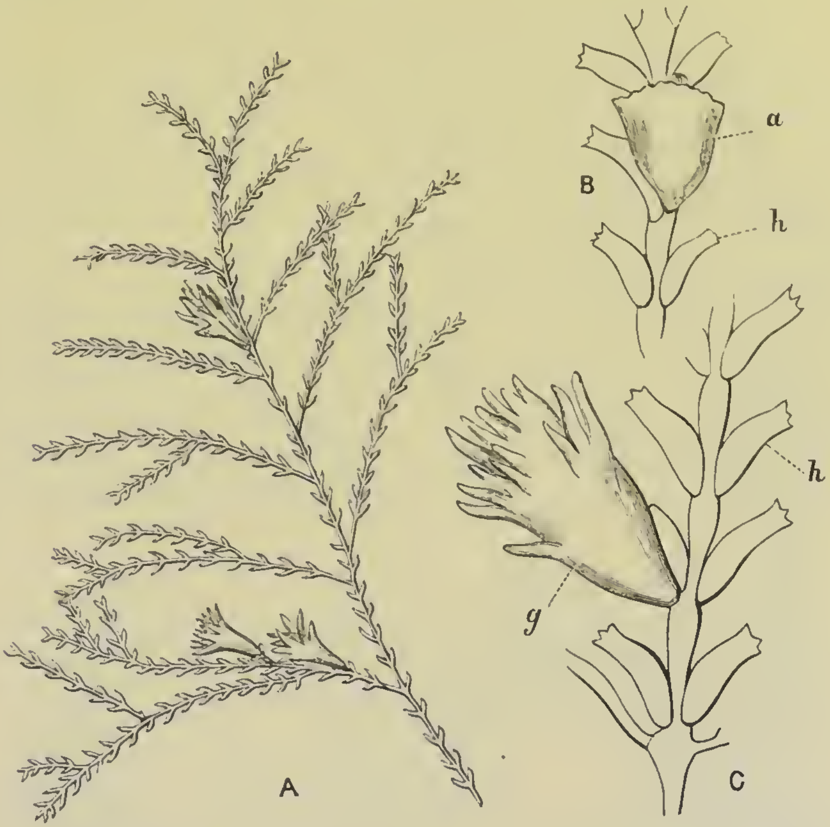

Fig. 64.—Sertularida. A, Portion of the colony of *Diphasia* (*Sertularia*) *tamarisca*, of the natural size, showing hydrothecæ and female ovarian capsules (gonangia). B and C, Portions of different branches of the same, enlarged: *h* Hydrothecæ; *a* Male gonangium; *g* Female gonangium. (After Hincks.)

its closure. Owing to the presence of "hydrothecæ," the name of "Calyptoblastic Hydroids" has been proposed by Professor Allman for the Sertularians and Campanularians. In all these forms, also, the generative buds are similarly enclosed in chitinous receptacles—the so-called "gonothecæ" or "gonangia." The cœnosarc generally consists of a main stem—or "hydrocaulus"—with many branches; and it is so plant-like in appearance that the common *Thecaphora* are almost always mistaken for sea-weeds by visitors at the sea-side. It is invested by a strong corneous or chitinous covering, or "periderm."

SUB-ORDER I. SERTULARIDA.—The Sertularians or "Sea-firs" are *Thecaphora* in which the hydrothecæ are sessile, and

placed on the sides of the cœnosarc (fig. 64); while the generative buds are not detached from the parent-colony as free Medusoids. In the typical Sertularians, the cœnosarc carries a row of hydrothecæ on its two sides; but in the Plumularians only a single row of polypites is developed (fig. 67).

The polypites in the Sertularians are sessile or sub-sessile, hydra-form, and in all essential respects identical with those of the *Corynida*, though usually smaller. Each polypite consists of a soft, contractile and extensile body, which is furnished at its distal extremity with a mouth and a circlet of prehensile tentacles, richly furnished with thread-cells. The tentacles have an indistinctly alternate arrangement. The mouth is simple or lobed, and is placed, in many cases, at the extremity of a more or less prominent extensile and contractile proboscis. The mouth opens into a chamber which occupies the whole length of the polypite, and is to be regarded as the combined body-cavity and digestive sac. At its lower end this chamber opens by a constricted aperture into a tubular cavity which is everywhere excavated in the substance of the cœnosarc. The

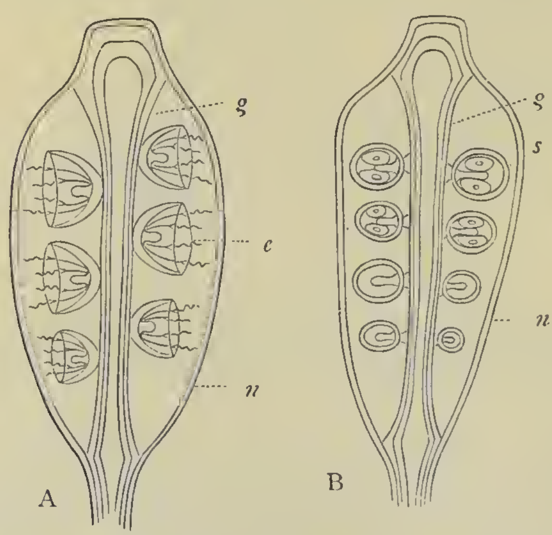

Fig. 65.—Diagrams of the gonothecæ, with their contents, of the Sertularians and Campanularians. *n* Chitinous envelope; *g* Central gonoblastidion or blastostyle; *c* Medusiform gonophores carried upon the blastostyle, each with a central manubrium in the walls of which the generative elements are produced; *s* Sporosacs carried upon the blastostyle, each with a central pillar (spadix) round which the ova are developed. (After Allman).

Fig. 66. — Ovarian capsule of *Diphasia* (*Sertularia*) *operculata*, Linn. (after Hincks). Greatly enlarged.

nutrient particles obtained by each polypite thus serve for the support of the whole colony, and are distributed throughout the entire organism. The nutritive fluid prepared in the in-

terior of each polypite gains access through the above-mentioned aperture to the cavity of the cœnosarc, which by the combined exertions of the whole assemblage of polypites thus becomes filled with a granular nutritive liquid. The cœnosarcal fluid is in constant movement, circulating through all parts of the colony, and thus maintaining its vitality, the cause of the movement being probably due in part, at any rate, to the existence of vibrating cilia. The generative buds (gonophores or ovarian vesicles) are usually supported upon gonoblastidia, and do not become detached in the true Sertularids. They are developed in chitinous receptacles known as "gonothecæ" (figs. 65, 66).

Sometimes the "gonangium" or "gonotheca" contains only a single gonophore, but more commonly it contains several, which increase in maturity as we recede from the base of the gonoblastidion (or blastostyle) and approach its summit (fig. 65, B). The buds carried on the sides of the blastostyle may have the form either of sporosacs or of medusoids. The ova may be directly discharged into the surrounding water, or may be retained for some time in a peculiar receptacle, "where they undergo further development, and which is supported upon the summit of the gonangium, and lies entirely external to its cavity" (Allman).

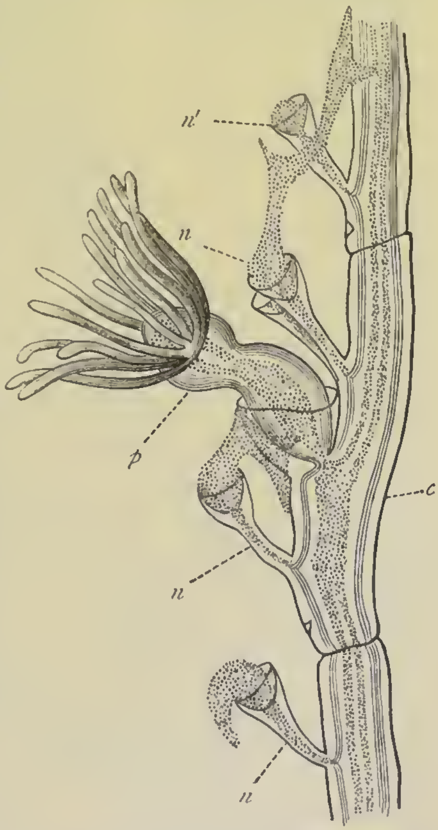

Fig. 67.—Portion of a branch of *Antennularia antennina*, enlarged. (After Allman.) *p* One of the polypites; *n n n* Nematophores emitting pseudopodial filaments of sarcode; *n'* Nematophore with its sarcodic contents quiescent; *c* Cœnosarc enclosed within the polypary.

In *Plumularia* and some of its allies there occur certain peculiar structures, to which the name of "nematophores" has been applied. Each of these consists of a process of the cœnosarc, which is invested by the horny polypary, with the exception of the distal extremity, which remains open. The nematophores are sometimes fixed, sometimes movable. They "constitute cup-like appendages (fig. 67, *n n*) formed

of chitine, and filled with protoplasm, which has the power of emitting pseudopodia or amœboid prolongations of its substance, and having their cavity in communication with that of the common tube of the hydrocaulus" (Allman). Whilst part of the sarcode in each nematophore is capable of being extended in long filaments resembling the pseudopodia of an *Amœba*, another portion is charged with large thread-cells, and is not capable of emission in this way. The function of these extraordinarily modified zoöids is uncertain.

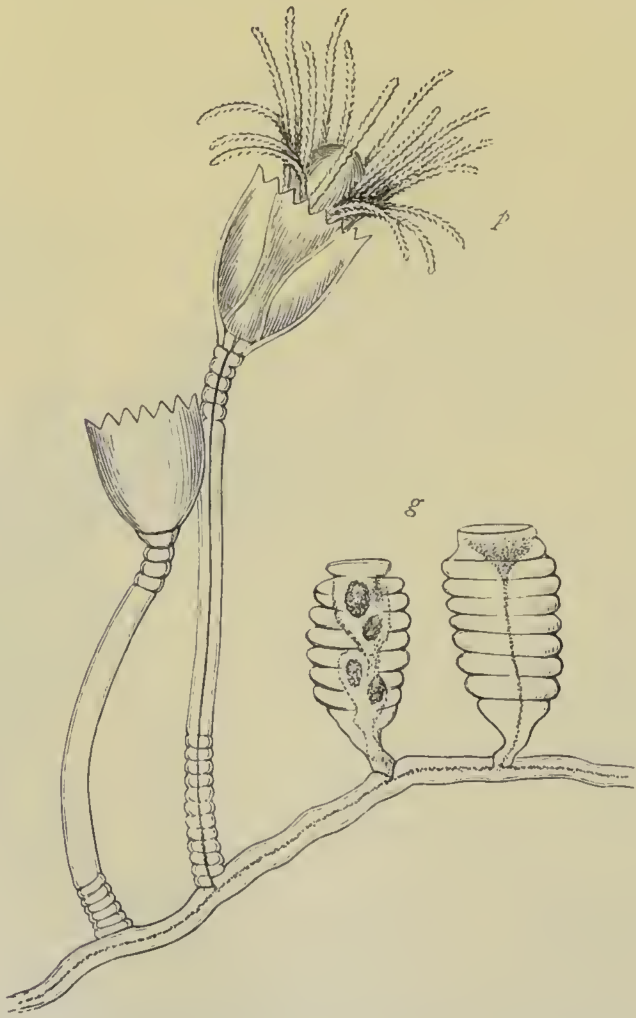

Fig. 68.—Portion of the colony of *Clytia* (*Campanularia Johnstoni*, magnified. *p* Nutritive zoöid ; *g* Capsules in which the reproductive zoöids are produced.

SUB-ORDER II. CAMPANULARIDA.—The members of this order are closely allied to the *Sertularida ;* so closely, indeed, that

they are very often united together into a single group. The chief difference consists in the fact that the hydrothecæ of the *Campanularida*, with their contained polypites, are supported upon conspicuous stalks, thus being terminal in position (fig. 68); whilst in the *Sertularida* they are sessile or subsessile, and are placed laterally upon the branchlets. The gonophores also in the *Campanularida* are usually detached as free-swimming medusoids, whereas they remain permanently attached in the *Sertularians*. Each medusoid consists of a little transparent glassy bell, from the under surface of which there is suspended a modified polypite, in the form of a "manubrium" (fig. 69). The whole organism swims gaily through the water, propelled by the contractions of the bell or disc (*gonocalyx*); and no one would now suspect that it was in any way related to the fixed plant-like zoophyte from which it was originally budded off. The central polypite is furnished with a mouth at its distal end, and the mouth opens into a digestive sac. From the proximal end of this stomach proceed four radiating canals which extend to the circumference of the disc, where they all open into a single circular vessel surrounding the mouth of the bell. From the margins of the disc hang also a number of delicate extensile filaments or tentacles; and the circumference is still further adorned with a series of brightly-coloured spots, which are probably organs of sense. The mouth of the bell is partially closed by a delicate transparent membrane or shelf, the so-called "veil." Thus constituted, these beautiful little beings lead an independent and locomotive existence for a longer or shorter period. Ultimately, the essential elements of reproduction are developed in special organs, situated in the course of the radiating canals of the disc. The resulting embryos are ciliated and free-swimming, but ultimately fix themselves, and develop into the plant-like colony from which fresh medusoids may be budded off. The ova in the medusiform gonophores are usually developed in

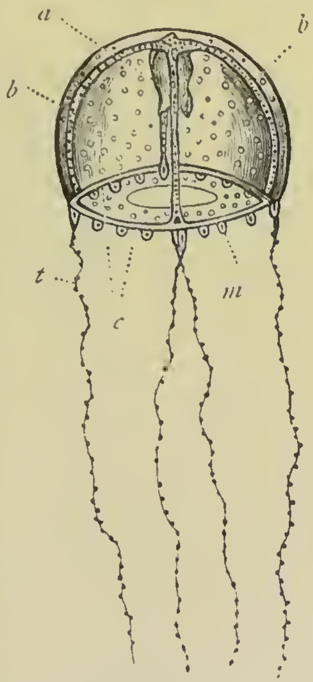

Fig. 69.—Free medusiform gonophore of *Clytia Johnstoni* (after Hincks). *a* Central polypite or manubrium; *b b* Radiating gastro-vascular canals; *c* Circular canal; *m* Marginal bodies; *t* Tentacles.

the course of the gonocalycine canals, and not between the ectoderm and endoderm of the manubrium, as is the case in the *Corynida*. Examples of the order are *Campanularia*, *Obelia*, *Laomedea*, &c.

ORDER IV. THECOMEDUSÆ.—Professor Allman has recently described, under the name of *Stephanoscyphus mirabilis*, a very remarkable Hydrozoön, which he believes to form the type of a new order. This singular organism is invariably associated with a species of sponge, in the substance of which it is embedded. It consists of a congeries of chitinous tubes, which permeate the sponge-substance, and which open on its surface by large openings resembling oscula. At their bases the tubes are connected by horizontal branches, and they expand widely as they approach the surface, where their contents become developed into a remarkable body, which has the power of extending itself beyond the mouth of the tube, and again of withdrawing within it. This body is furnished with a crown of tentacles, and is essentially *medusiform* in its structure. There is a circular canal at the base of the tentacular crown, surrounding the central opening, with four radiating canals proceeding backwards from this; but no lithocysts, ocelli, nor velum have been detected. For this curious organism, Professor Allman proposes the formation of a new order under the name of *Thecomedusæ*.

ORDER V. TRACHYMEDUSÆ (*Acalephæ*, in part).—The organisms included in this order are *free-swimming medusiform animals, in which the body is composed of a single swimming-bell* ("*nectocalyx*"), *from the roof of which is suspended a single polypite. A system of gastro-vascular canals* (*four*, *six*, *or eight in number*) *is developed in the walls of the swimming-bell; and the reproductive organs are developed in the course of the radiating canals. The swimming-bell is firm or semi-cartilaginous in consistence, and the tentacles are stiff and solid.*

The *Trachymedusæ* form a peculiar group of the organisms commonly known as "Jelly-fishes," and present the closest resemblance in general appearance to the free-swimming medusiform gonophores of the fixed Hydroid Zoophytes. The body consists of a single, gelatinous, bell-shaped swimming-bell ("nectocalyx"), the substance of which is usually strengthened by cartilaginous ridges. The open mouth of the bell ("codonostoma") is restricted by the development of an in-growing membranous shelf or "velum," and from the roof of the bell is suspended a single polypite ("the manubrium"). The alimentary cavity of the polypite is prolonged at its upper end into four, six, or eight simple canals, which radiate outwards to the

margin of the bell, where they are connected with a circular canal running round the circumference of the nectocalyx (fig. 70); the whole constituting the system of the "gastro-vascular" or "nectocalycine" canals. From the margin of the nectocalyx depend marginal tentacles, which are solid, and are

Fig. 70.—*Carmarina* (*Geryonia*) *hastata*, one of the *Trachymedusæ*, showing the swimming-bell with its canals, the central polypite, and the marginal tentacles and sense-organs.

rigid or slightly movable. Also around the circumference of the swimming-bell are disposed certain "marginal bodies," which are to be regarded as organs of sense, and as being of the nature of auditory organs. These have the form of projecting filaments, furnished at their bases with a sac ("otocyst") containing fluid, and having mineral particles in its interior. These marginal auditory organs receive nerve-filaments from a double nerve-ring which runs round the circumference of the bell. The reproductive organs (fig. 71, *o*) are placed in the course of the radiating nectocalycine canals. Lastly, development in the *Trachymedusæ* is direct, the embryo becoming

converted into the adult directly, without the intervention of an intermediate fixed and sexless stage.

From the above description, it will be seen that there exists

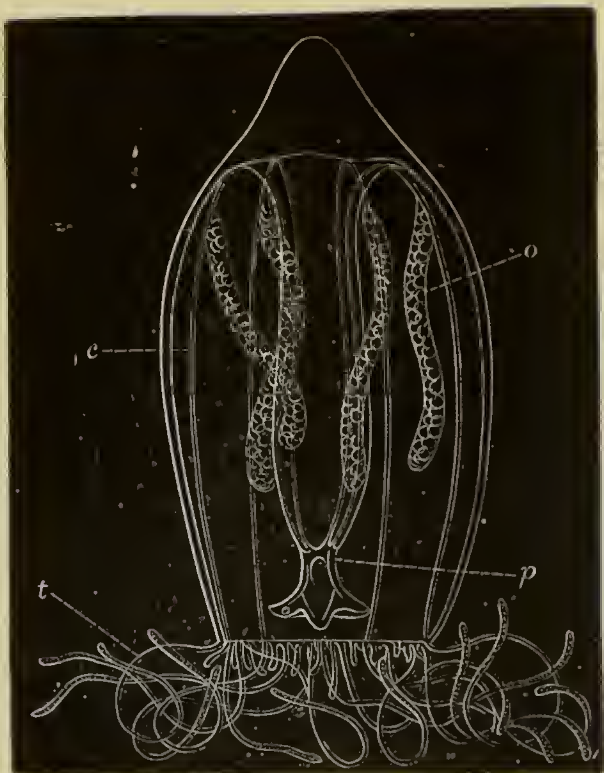

Fig. 71.—*Trachynema digitale*, a naked-eyed Medusa, female, enlarged. (After A. Agassiz.) *p* Manubrium or central polypite; *t* One of the tentacles; *c* One of the gastro-vascular canals; *o* One of the ovaries.

a close superficial resemblance between the *Trachymedusæ* and the free medusiform gonophores of the *Corynida* and *Thecaphora*. In both sets of forms the organism consists of a single swimming-bell enclosing a single polypite, and in both the mouth of the bell is partially constricted by the development of a shelf-like velum. From the presence of this "veil" (which is wanting in the *Acraspeda*), the name of "Craspedote Medusæ" has been applied as a common designation to both these groups of organisms. In both, again, the "gastro-vascular" canals are simple in structure and few in number (four, six, or eight), in which respect both differ from the great Sea-blubbers (*Acraspeda*). In both, finally, there is a double marginal nerve-ring, and the marginal sense-organs are so situated on the edge of the swimming-bell that they are exposed to

view. Hence the name of "Naked-eyed Medusæ" (*Gymnophthalmata*) formerly given to these organisms.

On the other hand, the *Trachymedusæ* differ from the free medusiform gonophores of the fixed Hydroids in the following characters:—

1. The nectocalyx of the *Trachymedusæ* is of a firmer consistence than in the medusiform gonophores, and is often strengthened by cartilaginous or epithelial ridges.

2. The tentacles of the *Trachymedusæ* are solid throughout, and are either quite rigid, or are capable of slight movement. The tentacles of the medusiform gonophores are, on the other hand, hollow, their cavities communicating with circular gastro-vascular canal, and they are therefore flexible.

3. The "marginal bodies" of the *Trachymedusæ*, as already seen, are auditory in function, and consist of an "otocyst" furnished with delicate auditory hairs, and connected with projecting filaments. On the other hand, in the medusiform gonophores the "marginal bodies" are of two kinds, which are usually not associated with one another. One class of these marginal bodies (fig. 72, C) comprises vesicular structures ("lithocysts") which are placed on the margin of the swimming-bell, and consist of a sac filled with a transparent fluid in which are immersed one or two apparently calcareous concretions or some minute crystals. These organs are probably auditory in function. The marginal bodies of the second class (fig. 72, *b*) are usually not developed along with the preceding, and have the form of masses of pigment enclosed in little cavities at the base of the tentacles. These so-called "eye-specks" or "ocelli" may or may not have in their interior a refracting body in addition to the pigment. They are supposed to be rudimentary organs of vision, and their exposed position on the edge of the swimming-bell gave rise to the name of "Naked-eyed Medusæ," applied by Edward Forbes to the jelly-fishes which possess these structures.

Fig. 72.—Margin of the swimming-bell of the medusiform gonophore of *Podocoryne*, greatly magnified. (After Hincks.) *a* Circular canal; *b* Ocellus; C, Auditory sac or lithocyst; *c* Calcareous concretion of lithocyst; *d* Tentacle.

4. Lastly, the *Trachymedusæ* develop themselves *directly*, the ovum giving rise to a medusa similar to the parent. On the other hand, the medusiform gonophores produce ova which are developed into the sexless colony from which the gonophores were budded off, an "alternation of generations" being thus established.

The *Trachymedusæ* are inhabitants of the sea,* and comprise the three families of the *Trachymedusæ*, *Æginidæ*, and *Geryonidæ*. In the *Æginidæ* the radiating gastro-vascular canals are replaced by long pouch-like extensions of the gastric cavity.

CHAPTER IX.

SIPHONOPHORA.

SUB-CLASS II. SIPHONOPHORA. — The members of this sub-class constitute the so-called "Oceanic *Hydrozoa*," and are characterised by the possession of a "*free and oceanic hydrosoma, consisting of several polypites united by a flexible, contractile, unbranched or slightly-branched cœnosarc, the proximal end of which is usually furnished with 'nectocalyces,' and is dilated into a 'somatocyst' or into a 'pneumatophore'*" (Greene).

All the *Siphonophora* are unattached, and permanently free, and all are composite. They are singularly delicate organisms, mostly found at the surface of tropical seas, the Portuguese man-of-war (*Physalia*) being the most familiar member of the group. The sub-class is divided into two orders—viz., the *Calycophoridæ* and the *Physophoridæ*.

ORDER I. CALYCOPHORIDÆ. — This order includes those *Siphonophora* whose *hydrosoma is free and oceanic, and is propelled by "nectocalyces" attached to its proximal end. The hydrosoma consists of several polypites, united by an unbranched cœnosarc, which is highly flexible and contractile, and never develops a hard cuticular layer. The proximal end of the hydrosoma is modified into a peculiar cavity called the "somatocyst." The reproductive organs are in the form of medusiform gonophores produced by budding from the peduncles of the polypites.*

In all the *Calycophoridæ* the cœnosarc is filiform, cylindrical,

* A little Medusoid (*Limnocodium Sowerbyi*) has been found in great numbers in the fresh-water tank containing the *Victoria regia* in the Regent's Park Botanic Garden; and the structure of this allies it closely to the marine *Trachymedusæ*.

unbranched, and highly contractile, this last property being due to the presence of abundant muscular fibres. "The proximal end of the cœnosarc dilates a little, and becomes ciliated internally, forming a small chamber" which communicates with the nectocalycine canals. "At its upper end this chamber is a little constricted, and so passes, by a more or less narrowed channel, into a variously-shaped sac, whose walls are directly continuous with its own, and which will henceforward be termed the *somatocyst* (fig. 73, 3 *b*). The endoderm of this sac is cili-

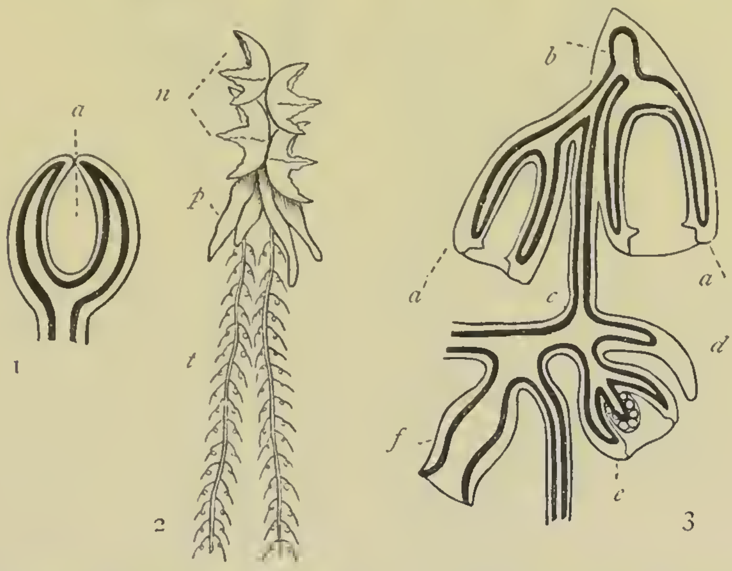

Fig. 73.—Morphology of the Oceanic Hydrozoa. 1. Diagram of the proximal extremity of a *Physophorid: a* Pneumatocyst. 2. *Vogtia pentacantha*, one of the *Calycophoridæ: n* Nectocalyces; *p* Polypites; *t* Tentacles. 3. Diagram of a *Calycophorid: a a'* Proximal and distal nectocalyces; *b* Somatocyst; *c* Cœnosarc; *d* Hydrophyllium or bract; *e* Medusiform gonophore; *f* Polypite. The dark lines in figs. 1 and 3 indicate the endoderm, the light line with the clear space indicates the ectoderm. (After Huxley.)

ated, and it is generally so immensely vacuolated as almost to obliterate the internal cavity, and give the organ the appearance of a cellular mass" (Huxley). The polypites in the *Calycophoridæ* often show a well-marked division into three portions, termed respectively the proximal, median, and distal divisions. Of these the "proximal" division is somewhat contracted, and forms a species of peduncle, which often carries appendages. The "median" portion is the widest, and may be termed the "gastric division," as in it the process of digestion is carried on. It is usually separated from the proximal division by a valvular inflection of the endoderm, which is known as the "pyloric valve." The polypites have only one tentacle "de-

veloped near their basal or proximal ends, and provided with lateral branches ending in saccular cavities," and furnished with numerous thread-cells (fig. 74, *t*). The proximal ends of the polypites usually bear certain overlapping plates of a pro-

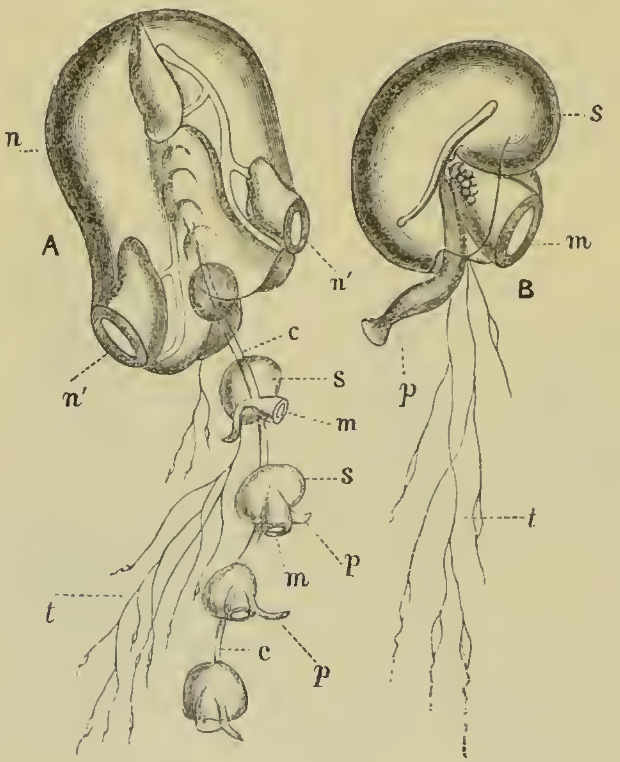

Fig. 74.—Calycophoridæ. A, Upper portion of the colony of *Praya maxima*, of the natural size: *n* The proximal nectocalyces; *n' n'* Mouths of the same; *c c* Cœnosarc, carrying polypites (*p p*) at intervals, along with their swimming-bells (*s s*), the openings of these being indicated by the letters *m m*; *t* Tentacles. B, A single polypite of the same (*p*), separated from the cœnosarc, and enlarged, with its swimming-bell (*s*), the opening of the bell (*m*), and the tentacles (*t*). (After Gegenbaur.)

tective nature, which are termed "hydrophyllia" or "bracts." They are composed of processes of both ectoderm and endoderm (fig. 73, 3 *d*), and they always contain a diverticulum from the somatic cavity, which is called a "phyllocyst." The *Calycophoridæ* always possess swimming-bells, or "nectocalyces," by the contractions of which the hydrosoma is propelled through the water (fig. 73, 2). The nectocalyx in structure is very similar to the "gonocalyx" of a medusiform gonophore, as already described; but the former is devoid of the gastric or genital sac—the "manubrium"—possessed by the latter. Each nectocalyx consists of a bell-shaped cup, attached by its base to the hydrosoma, and provided with a muscular lining in the

interior of its cavity, or "nectosac." There is also always a "velum" or "veil," in the form of a membrane attached to the mouth of the nectosac round its entire margin, and leaving a central aperture. The peduncle by which the nectocalyx is attached to the hydrosoma conveys a canal from the somatic cavity which dilates into a ciliated chamber, and gives off at least four radiating canals, which proceed to the circumference of the bell, where they are united by a circular vessel; the entire system constituting what is known as the system of the "nectocalycine canals." In the typical *Calycophoridæ* two nectocalyces only are present, but in some genera there are more. In *Praya* the two nectocalyces are so apposed to one another that a sort of canal is formed by the union of two grooves, one of which exists on the side of each nectocalyx. This chamber, which is present in a more or less complete form in all the genera, is termed the "hydrœcium," and the cœnosarc can be retracted within it for protection.

The reproductive bodies in the *Calycophoridæ* are in the form of medusiform gonophores, which are budded from the peduncles of the polypites, becoming, in many instances, detached to lead an independent existence. In some *Calycophoridæ*, as in *Abyla*, "each segment of the cœnosarc, provided with a polypite, its tentacle, reproductive organ, and hydrophyllium, as it acquires a certain size, becomes detached, and leads an independent life—the calyx of its reproductive organ serving it as a propulsive apparatus. In this condition it may acquire two or three times the dimensions it had when attached, and some of its parts may become wonderfully altered in form" (Huxley). To these detached reproductive portions of adult *Calycophoridæ* the term "Diphyozoöids" has been applied.

As regards the development of the *Calycophoridæ*, "not only the new polypites, but the new nectocalyces and reproductive organs, and even the branches of the tentacles, are developed on the proximal side of the old ones; so that the distal appendages are the oldest" (Huxley). The process of development is therefore the reverse of what obtains amongst the *Hydroida*.

Diphyes (fig. 75), which may be taken as the type of the *Calycophoridæ*, consists of a delicate filiform cœnosarc, provided proximally with two large mitre-shaped nectocalyces (v v'), of which one lies entirely on the distal side of the other. The pointed apex of the distal nectocalyx is received into a special cavity in the proximal nectocalyx. The "hydrœcium" (h) is formed partially by this chamber in the nectocalyx, and partially by an arched groove prolonged upon the inner surface of the distal nectocalyx, within which the cœnosarc moves freely up and down, and can be entirely retracted if necessary. The upper part of the cœnosarc dilates into a small ciliated cavity, from which are given off two tubes, which proceed respectively to the distal and proximal nectocalyces, where they

open into the central chamber from which the nectocalycine canals take their rise. The upper portion of this small ciliated cavity is prolonged proximally into the larger chamber of the "somatocyst." The cœnosarc (*c*) bears polypites, each of which is protected by a delicate glassy "hydrophyllium."

ORDER II. PHYSOPHORIDÆ.—This second order of the *Oceanic Hydrozoa* comprises those *Siphonophora in which the hydrosoma consists of several polypites united by a flexible, contractile, unbranched or very slightly branched cœnosarc, the proximal extremity of which is modified into a "pneumatophore," and is sometimes provided with "nectocalyces." The polypites have either a single basal tentacle, or the tentacles arise directly from the cœnosarc. "Hydrophyllia" are commonly present. The reproductive bodies are developed upon gonoblastidia.*

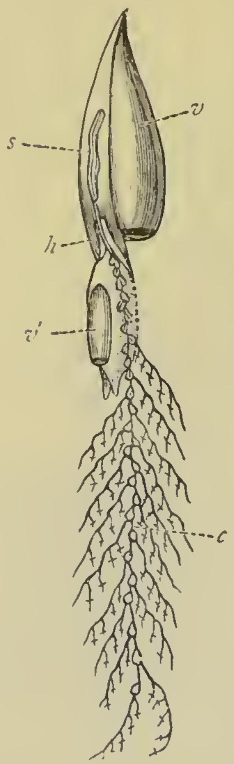

Fig. 75.—Calycophoridæ. *Diphyes appendiculata* (after Kölliker). *v* Proximal nectocalyx; *v'* Distal nectocalyx; *h* Hydrœcium; *c* Cœnosarc, carrying polypites each with its bract and tentacle.

The cœnosarc in the *Physophoridæ*, like that of the *Calycophoridæ*, is perfectly flexible and contractile; but it is not necessarily elongated, being sometimes spheroidal or discoidal. The proximal end of the cœnosarc "expands into a variously-shaped enlargement, whose walls consist of both ectoderm and endoderm, and which encloses a wide cavity in free communication with that of the cœnosarc, and, like it, full of the nutritive fluid. From the distal end, or apex, of this cavity depends a sac, variously shaped, but always with tough, strong, and elastic walls, composed of a substance which is stated to be similar to chitine in composition, and more or less completely filled with air" (Huxley). The large proximal dilatation of the cœnosarc is termed the "pneumatophore," whilst the chitinous air-sac which it contains is termed the "pneumatocyst" (fig. 73, 1). The pneumatocyst is held in position by the reflection of the endoderm of the pneumatophore over it, and it doubtless acts as a buoy or "float." In the Portuguese man-of-war (*Physalia*) the pneumatocyst communicates with the exterior by means of an aperture in the ectoderm of the pneumatophore. In *Velella* and *Porpita* the pneumatocyst communicates with the exterior by means of several similar

openings called "stigmata"; and from its distal surface depend numerous slender processes containing air, and known as "pneumatic filaments."

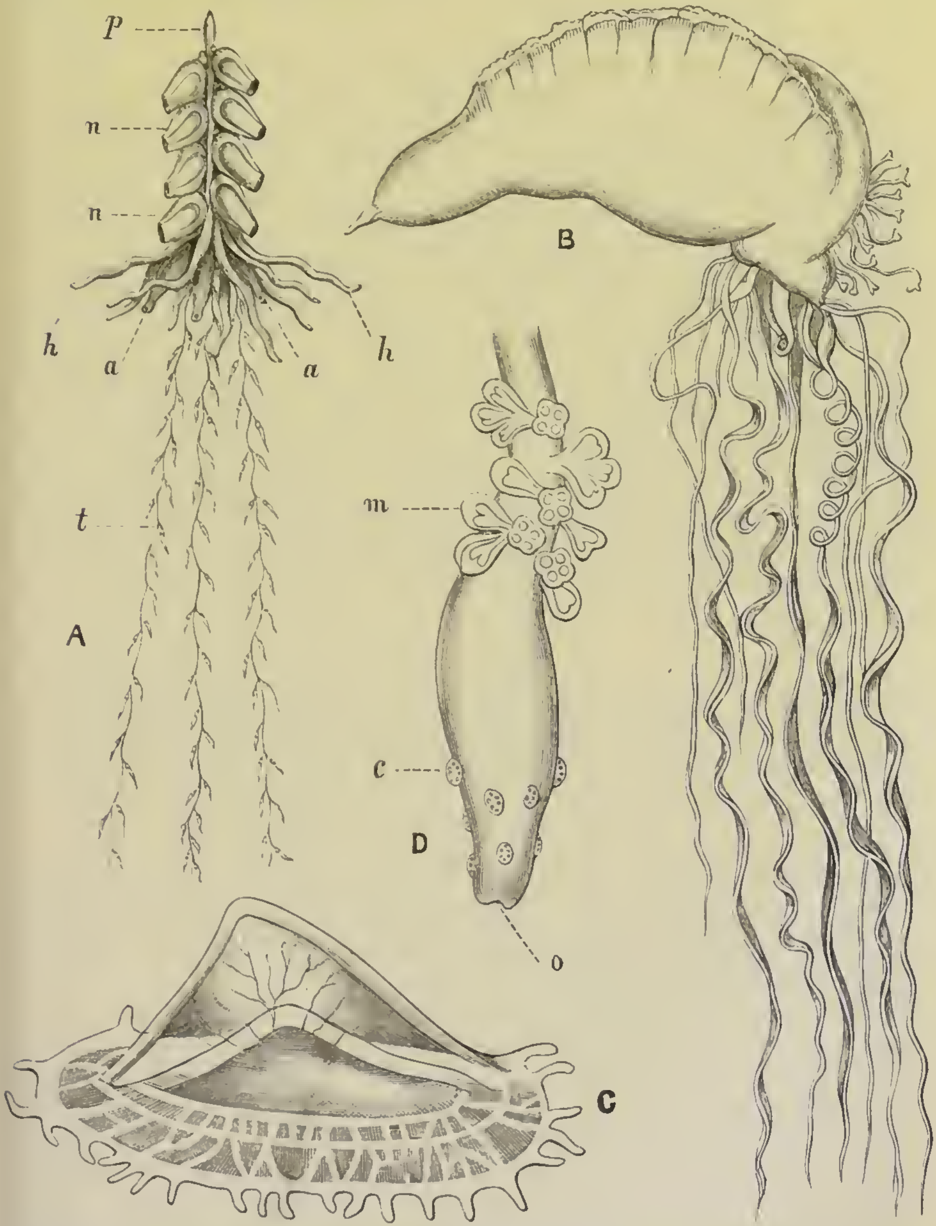

Fig. 76.—Physophoridæ. A, *Physophora Philippi:* *p* The pneumatophore; *n n* The nectocalyces; *h h* Hydrocysts; *a a* Polypites; *t* Tentacles. B, *Physalia pelagica.* C, *Velella spirans.* D, One of the smaller polypites (phyogemmaria) of the same, showing (*o*) the mouth, (*c*) elevations studded with thread-cells, and (*m*) medusoid buds.

The polypites of the *Physophoridæ* resemble those of the

Calycophoridæ in shape, but the tentacles have a much more complicated structure, and are sometimes many inches in length, as in *Physalia*. The "hydrophyllia" have essentially the same structure as those of the former order. There occur also in the *Physophoridæ* certain peculiar bodies, termed "hydrocysts" or "feelers" ("Fühler" and "Taster" of the Germans). These resemble immature polypites in shape, consisting of a prolongation of both ectoderm and endoderm, usually with a tentacle, and containing a diverticulum of the somatic cavity, the distal extremity being closed, and furnished with numerous large thread-cells. They are looked upon as "organs of prehension and touch," and they are in some respects analogous to the "nematophores" of the Plumularians.

As regards the reproductive organs, they are developed upon special processes or "gonoblastidia," and they may remain permanently attached, or they may be thrown off as free-swimming medusoids. In many of the *Physophoridæ* the male and female gonophores differ from one another in form and size, and they are then termed respectively "androphores" and "gynophores." As regards their development, the *Physophoridæ* obey the same general law as the *Calycophoridæ*.

In *Physophora* (fig. 76, A) the hydrosoma consists of a filiform cœnosarc, which bears the polypites and their appendages, and dilates proximally into a pneumatophore. Below this point the cœnosarc bears a double row of nectocalyces, which are channelled on their inner faces to allow of their attachment to the cœnosarc. There are no hydrophyllia, but there is a series of "hydrocysts" on the proximal side of the polypites.

Physalia, or the Portuguese man-of-war (fig. 76, B) is composed of a large, bladder-like, fusiform "float" or pneumatophore—sometimes from eight to nine inches in length—upon the under surface of which are arranged a number of polypites, together with highly contractile tentacles of great length, "hydrocysts," and reproductive organs. *Physaliæ* are of common occurrence, floating at the surface of tropical seas.

In *Velella* (fig. 76, C) the hydrosoma consists of a widely expanded pneumatophore of a rhomboidal shape, carrying upon its upper surface a diagonal vertical crest. Both the horizontal disc and the vertical crest are composed of a soft marginal "limb," and a central more consistent "firm part." "To the distal surface of the firm part of the disc are attached the several appendages, including—1, a single large polypite, nearly central in position; 2, numerous small gonoblastidia, which resemble polypites, and are termed 'phyogemmaria'; and, 3, the reproductive bodies to which these last give rise. The tentacles are attached, quite independently of the polypites, in a single series along the line where the firm part and limb of the disc unite. There are no hydrocysts, nectocalyces, or hydrophyllia. . . . On all sides the limb is traversed by an anastomosing system of canals, which are ciliated, and communicate with the cavities of the phyogemmaria and large central polypite" (Greene). The *Velellæ* float near the surface of the sea, with the vertical crest exposed.

CHAPTER X.

LUCERNARIDA AND GRAPTOLITOIDEA.

LUCERNARIDA.

SUB-CLASS III. LUCERNARIDA (*Scyphomedusæ; Acalephæ*, in part). — The members of this sub-class may be defined as *Hydrozoa in which the base of the hydrosoma is developed into disc-shaped or cup-like structure* (*the* "*umbrella*"), *in the walls of which the reproductive organs are produced. The edge of the umbrella is lobed, and no "veil" is present.* The sense-organs are placed on the under side of the disc, and are hidden from view.*

A large number of forms included in the *Lucernarida* were described by Edward Forbes under the name of *Steganopthalmate Medusæ*, being in external features in many respects similar to the *Trachymedusæ* and medusiform gonophores. These so-called "hidden-eyed" *Medusæ* are familiar to every one as "sea-blubbers" or "sea-jellies," and they occur in great numbers in the shallow parts of the sea. Besides these forms, we may include in this division the less familiar organisms of which *Lucernaria* itself is the type.

The *Lucernarida* may be divided into the two principal sections of the *Calycozoa* and the *Acraspeda*, of which the former includes only the small group of the *Lucernariadæ*.

SECTION A. CALYCOZOA.

ORDER LUCERNARIADÆ.—In the members of this group *the body is cup-shaped, and is fixed by a proximal hydrorhiza. It consists of a single polypite with four gastro-vascular pouches separated by as many narrow septa. The edge of the umbrella carries short tentacles, and the reproductive elements are developed in the primitive polypite, within the umbrella.*

In *Lucernaria* (fig. 77), which may be taken as the type of the order, the body is campanulate or cup-shaped, and is attached proximally at its smaller extremity by a hydrorhiza, which, however, like that of the *Hydra*, is not permanently fixed. When detached, the animal is able to swim with tolerable rapidity by means of the alternate contraction and expansion of the umbrella. Around the margin of the umbrella are

* If the *Charybdeæ* are included in this sub-class, the total absence of a velum is not a universal character, as these forms possess a veil, into which, however, the gastro-vascular canals send branches.

tufts of short, solid tentacular processes, and in its centre is a polypite with a quadrangular four-lobed mouth. The mouth opens into a gastric cavity which is prolonged at its four angles into four wide gastro-vascular pouches, between which are four narrow partitions. Each of these septa carries on each side a band-like generative organ, so that there are eight reproductive organs in all. Development is direct, the ciliated embryo becoming converted directly into the adult without the intervention of an intermediate sexless zoöid. Allied to *Lucernaria* are other genera (*Carduella*, *Depastrum*, &c.); all the known forms being marine, and being confined to northern seas.

Fig. 77.—Lucernariadæ. *Lucernaria auricula* attached to a piece of sea-weed. (After Johnston.)

SECTION B. ACRASPEDA (*Discophora*).

This section includes the most typical members of the *Lucernarida*, all of which are more or less medusiform, though they may pass through a hydraform stage in their development. In their adult condition they all possess a gelatinous disc or swimming-bell —the "umbrella"—formed of exceedingly loose connective-tissue saturated with sea-water. Histologically, the tissue of the umbrella may exhibit no formed elements; but it commonly consists of a network of fibres, and may contain in addition branched or radiated nucleated cells, the processes of which anastomose with one another. From the under side of the umbrella hangs a single polypite (greatly modified in the *Rhizostomata*); and the process of development may be direct, or may exhibit an "alternation of generations."

The swimming-bell or "umbrella" of the *Acraspeda* is superficially closely similar to the nectocalyx of one of the *Trachymedusæ* or of a medusiform gonophore; but it is distinguished by the following peculiarities: 1. The umbrella of the *Acraspeda* is not furnished with a velum, as is the nectocalyx of the Medusæ. [In the *Charybdeæ*, sometimes included here, a velum of a peculiar type is present.] From the absence of a velum, the members of this section are termed "Acras-

pedote Medusæ," to distinguish them from the so-called "Craspedote Medusæ," in which this structure is developed. 2. The radiating gastro-vascular canals are never less than eight in number, and they typically subdivide in the substance of the umbrella, so as to give rise to a network of vessels; whereas, in the Craspedote Medusæ, these canals are never more than eight, and do not form a network. 3. The margin of the umbrella is cut into lobes, and the marginal sense-organs are protected and hidden from view by processes of these lobes. Hence the name of "Hidden-eyed" Medusæ (*Steganophthalmata*) applied to these forms by Edward Forbes, to distinguish them from the "naked-eyed" or Craspedote Medusæ. 4. In place of the separate and unprotected auditory "vesicles" and "ocelli" of the Craspedote Medusæ, the marginal bodies of the *Acraspeda* consist of these bodies combined together into single organs, which are termed "lithocysts." 5. The nervous system has not the form of a double marginal nerve-cord, but of separated ganglia placed round the edge of the disc, and connected directly with the marginal bodies. There is also a nervous plexus developed in the inferior portion of the umbrella ("sub-umbrella"). 6. The gastric cavity is furnished on its inferior wall with numerous movable tentacular processes ("gastric filaments"), which appear to be connected with the process of digestion.

The *Acraspeda* may be divided into two sections, according as they have a polypite of the ordinary type, with a single central mouth (*Monostomata*), or have a specially modified polypite without a definite central mouth (*Rhizostomata*). In the former of these groups are comprised various "Sea-blubbers" which agree in their essential structural features, but differ in their mode of development. Thus in some cases (*Pelagidæ*) the ovum develops directly into a Steganophthalmate Medusid, which produces the reproductive organs, so that there is no "alternation of generations." In other cases, again, as in *Aurelia* and *Cyanea*, there is such an alternation, the Hidden-eyed Medusid being only *one* stage of the organism, and being preceded by a sexless hydraform stage (the Hydra-tuba).

Whether developed directly from a form like itself, or produced by fission from a fixed and sexless zoöid, the Steganophthalmate Medusid is in these monostomatous forms similarly constructed (figs. 78 and 80). It consists, namely, of a bell-shaped gelatinous disc, the "umbrella," from the roof of which is suspended a large polypite, the lips of which are extended into fringed or lobed processes often of considerable length,

"the folds of which serve as temporary receptacles for the ova in the earlier stages of their development." The polypite—manubrium or proboscis—is hollowed into a digestive sac, which communicates with a gastric cavity in the roof of the umbrella, from which arises a series of radiating canals, the so-called "gastro-vascular" or "chyl-aqueous canals." These canals, which are never less than eight in number, branch freely and anastomose as they pass towards the periphery of the umbrella, while the entire series is connected by a circular marginal canal. This, in turn, sends tubular processes into the marginal tentacles, which are often of great length. Besides the tentacles, the margin of the umbrella is furnished with a series of peculiar bodies, termed "lithocysts," each of which is protected by a sort of process or hood derived from the ectoderm, and consists essentially of a combined "vesicle" and "pigment-spot," such as have been described as occurring separately in the Craspedote *Medusæ*. These marginal bodies likewise communicate with the gastro-vascular canals. The reproductive organs are typically in the form of four folded bands (fig. 80, *r*), which project into as many special cavities (the "sub-genital pits") in the floor of the great gastric cavity. Being usually of some bright colour, the reproductive organs "form a conspicuous cross shining through the thickness of the disc" (Greene).

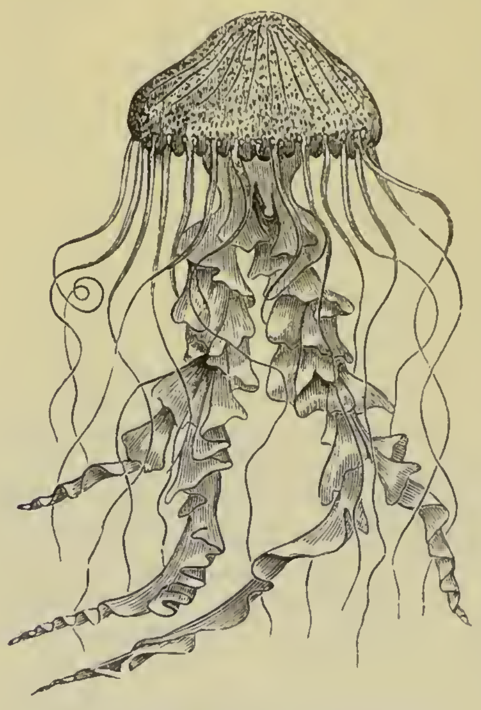

Fig. 78.—*Chrysaora hysoscella*, one of the *Pelagidæ*.

Such an Acraspedote *Medusa* as above described may constitute the entire organism (as in *Pelagia* and *Chrysaora*), and its ova may be directly developed into a body similar to itself. More usually, there is an alternation of generations, the ovum giving rise to a fixed and sexless zoöid from which the sexual zoöid, or Medusid, is produced by fission. The following is a summary of the life-history of those *Acraspeda* in which, as

in *Aurelia*, the latter method of development obtains. The embryo (fig. 79, *a*) is a free-swimming, oblong, ciliated body, termed a "planula," of a very minute size, and composed of

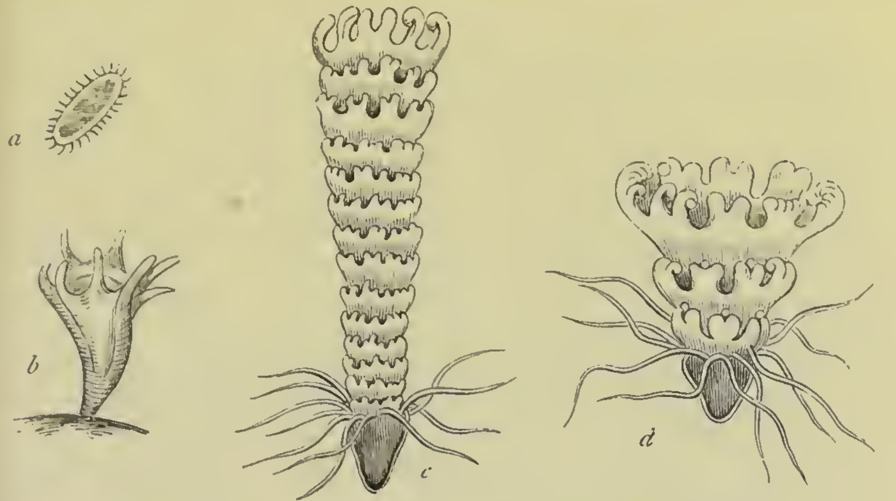

Fig. 79.—Development of *Aurelia*, one of the Acraspedote *Medusæ*. *a* Ciliated free-swimming embryo, or "planula"; *b* Hydra-tuba; *c* Hydra-tuba in which fission has considerably advanced, and the "Strobila" stage has been reached; *d* Hydra-tuba in which the fission has proceeded still further, and a large number of the segments have been already detached to lead an independent existence.

an outer and inner layer, enclosing a central cavity. The planula soon becomes pear-shaped, and a depression is formed at its larger end. "Next, the narrower end attaches itself to some submarine body, whilst the depression at the opposite extremity, becoming deeper and deeper, at length communicates with the interior cavity. Thus a mouth is formed, around which may be seen four small protuberances, the rudiments of tentacula. In the interspaces of these four new tentacles arise; others in quick succession make their appearance, until a circlet of numerous filiform appendages, containing thread-cells, surrounds the distal margin of the 'Hydra-tuba' (*b*), as the young organism at this stage of its career has been termed by Sir J. G. Dalyell. The mouth, in the meantime, from being a mere quadrilateral orifice, grows and lengthens itself so as to constitute a true polypite, occupying the axis of the inverted umbrella or disc, which supports the marginal tentacles. The space between the walls of the polypite and umbrella is divided into longitudinal canals, whose relations to the rest of the organism, and, indeed, the whole structure of *Hydra-tuba*, closely resemble what may be seen in *Lucernaria*" (Greene, 'Manual of Cœlenterata'). The *Hydra-tuba* thus constitutes the fixed

"Lucernaroid," or the "trophosome" of one of the *Acraspeda*. In height it is less than half an inch, but it possesses the power of forming, by gemmation, large colonies, which may remain in this condition for years, the organism itself being incapable of producing the essential elements of generation. Under certain circumstances, however, reproductive zoöids are produced by the following singular process (fig. 79). The *Hydra-tuba* becomes elongated, and becomes marked by a series of grooves or circular indentations, extending transversely across the body, from a little below the tentacles to a little above the fixed extremity. At this stage the organism was described as new by Sars, under the name "*Scyphistoma*." The annulations or constrictions go on deepening and become lobed at their margin, till the *Scyphistoma* assumes the aspect of a pile of saucers, arranged one upon another with their concave surfaces upwards. This stage was described by Sars under the name of "*Strobila*" (*c*). The tentacular fringe which originally surrounded the margin of the *Hydra-tuba* now disappears, and a new circlet is developed below the annulations, at a point a little above the fixed extremity of the *Strobila* (*c*). "The disc-like segments above the tentacles gradually fall off, and, swimming freely by the contractions of the lobed margin which each presents, they have been described by Eschscholtz as true *Medusidæ* under the name of *Ephyræ* (*d*)." Each *Ephyra*, however, soon shows its true nature by becoming developed into a free-swimming reproductive zoöid, usually of large size, with umbrella, hooded lithocysts, and tentacles, constituting, in fact, a *Steganophthalmate Medusa* (fig. 80). The reproductive zoöid now swims freely by the contraction of its umbrella, and it eats voraciously and increases largely in size. The essential elements of generation are then developed in special cavities in the umbrella, and the fertilised ova, when liberated, appear as free-swimming, ciliated "planulæ," which fix themselves, become *Hydra-tubæ*, and commence again the cycle of phenomena which we have above described.

As regards the *size* of these reproductive zoöids as compared with the organism by which they are given off, it may be mentioned that the umbrella of *Cyanea arctica* has been found in one specimen to be seven feet in diameter, with tentacles more than fifty feet in length, the fixed *Lucernaroid* from which it was produced not being more than half an inch in height.

The Rhizostomatous types of the *Acraspeda*, as represented by *Rhizostoma* itself (figs. 81, 82), pass through a development essentially similar to that seen in the typical Monostomatous

forms. They differ from the latter, however, in not possessing tentacles on the margin of the umbrella, and in having the simple central polypite replaced by a composite dendriform

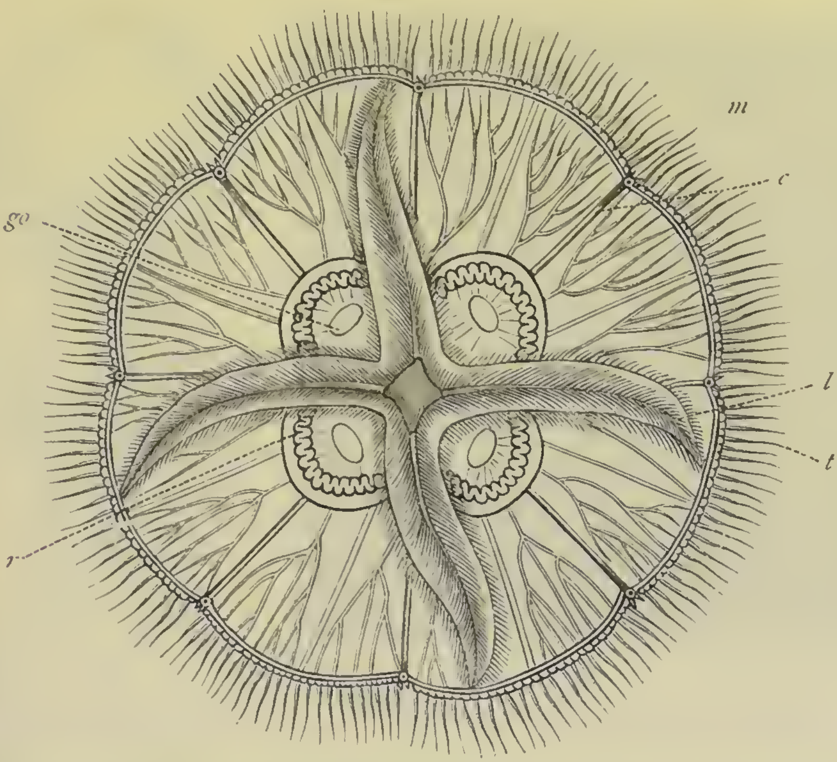

Fig. 80.—*Aurelia aurita*, seen from the under surface, reduced in size (after Claus and Sedgwick). *l* One of the four oral lobes, in the centre of which is placed the mouth; *t* Tentacles attached to the lobed margin of the umbrella; *c* One of the radial gastro-vascular canals; *m* One of the marginal bodies; *r* Reproductive organ; *go* Opening of one of the four sub-genital pouches.

process, which projects far below the umbrella. This central tree-like mass is divided into branches ("stomatodendra"), which are covered with club-shaped tentacles, interspersed with tufted suctorial tubes furnished with terminal apertures. By Professor Huxley these suctorial tubes have been regarded as modified polypites. There is in reality, however, but a single central polypite, the mouth of which becomes obliterated at an early stage of development; and the apparent polypites of the "stomatodendra" are really mouth-like apertures formed by the extraordinarily complex manner in which the oral lobes are folded, and serving for the admission of nutritive particles.

The Acraspedote *Medusæ* are wholly marine; and they not only attain a comparatively gigantic, and sometimes an actually colossal, size, but they are found in countless numbers in most

oceans. Usually they swim near the surface, and show themselves very sensitive to alterations of light and temperature. In some cases, they crawl about on the sea-bottom in shallow

Fig. 81.— Rhizostomata. Generative zoöid of *Rhizostoma* (after Owen). *a* Umbrella; *bb* "Stomatodendra," covered with clavate tentacles and minute suctorial tubes; *c c* Anastomosing network of canals.

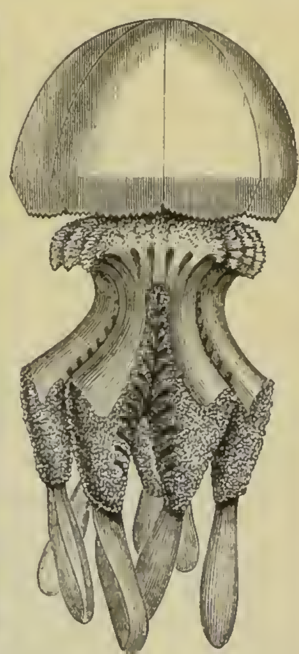

Fig. 82.—Generative zoöid of *Rhizostoma pulmo*, reduced in size. (After Gosse.)

water. Sometimes they have been seen to lie at the bottom, with the base of the umbrella turned downwards and the arms directed upwards, expanded like a flower. Often they shelter various "commensals" beneath their discs, especially fishes and different forms of Crustaceans. They are often brightly coloured, and many of them phosphoresce brilliantly when irritated. In spite of their want of any hard structures, they, like some of the Craspedote *Medusæ*, are not absolutely unknown as fossils, the impressions left by their stranded discs on the mud of the sea-shore being sometimes found in fine-grained rocks. In this way, it is known that they date from the Jurassic period, at any rate.

Graptolitoidea.

Sub-class IV. Graptolitoidea (= Rhabdophora, Allman).—The organisms included at present under this head are all extinct, and they are in many respects so dissimilar, and their structure is so far from being entirely understood, that it is

doubtful if any definition can be framed which will include *all* the supposed members of the family. The following definition, however, will include all the most typical Graptolites :—

Hydrosoma compound, occasionally branched, consisting of numerous polypites united by a cœnosarc; the latter being enclosed in a strong, tubular, chitinous polypary, whilst the former were protected by hydrothecæ. In the great majority of Graptolites the hydrosoma was certainly unattached; but in some aberrant forms—doubtfully belonging to the sub-class —there is reason to believe that the hydrosoma was fixed. In many cases the hydrosoma was strengthened by a chitinous rod, the "solid axis" or "virgula," somewhat analogous to the chitinous rod which strengthens the polyzoary in the singular Polyzoön *Rhabdopleura*. This axial rod lies in a groove on the dorsal side of the polypary (*i.e.*, on the side opposite to that on which the hydrothecæ are developed), and it may be prolonged beyond one or both ends of the colony. The polypary is typically furnished at its proximal end with a minute triangular or dagger-shaped spine (the "sicula") which represents the embryonic skeleton.

Taking such a simple Graptolite as *Monograptus priodon* (fig. 83) as the type of the sub-class, the hydrosoma is found to consist of the "axis" ("virgula"), the cœnosarc ("common canal"), and the hydrothecæ ("cellules"). The entire polypary is corneous and flexible, and the "axis" is a cylindrical fibre or rod, apparently really hollow, which gives support to the colony, and is often prolonged beyond the distal end of the hydrosoma. The proximal end of the hydrosoma is also provided with a short triangular process (the "sicula"), this being in reality the embryonic polypary. Running parallel with the axis is the tubular canal which enclosed the cœnosarc, and from this on one side spring the little cups or "hydrothecæ," in which the polypites were contained.

The entire structure of a simple Graptolite is, therefore, in many respects similar to what is seen in the recent Sertularians; but the "axis" and "sicula" are structures peculiar to the present group. Moreover, it is certain that the typical Graptolites were free-floating organisms, and were not attached by a hydrorhiza. On the other hand, there are certain forms which have usually been placed among the Graptolites (*e.g.*, *Ptilograptus* and *Dendrograptus*), in which the polypary was branched and possibly attached to foreign bodies.

Besides the simple ("monoprionidian") Graptolites, with a row of hydrothecæ on one side only (fig. 83), there are other ("diprionidian") forms, with a row of hydrothecæ on each side (fig. 84), and with the axis running

through the centre of the polypary, in the double partition which separates the two halves of the hydrosoma. In still other ("tetraprionidian") forms, there are four rows of hydrothecæ. In certain genera, also, there is found a corneous disc or cup at the proximal end of the polypary, which may be compared with the "float" or "pneumatophore" of the *Physophoridæ*.

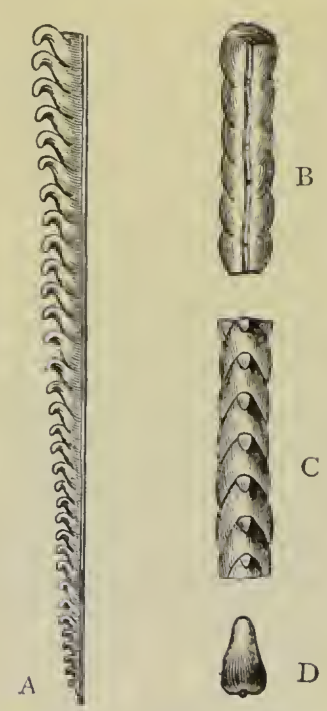

Fig. 83.—A, *Monograptus priodon*, Bronn, preserved in relief—lateral view, slightly enlarged; B, Dorsal view of a fragment of the same species—considerably enlarged; C, Front view of a fragment of the same, showing the mouths of the cellules—much enlarged; D, Transverse section of the same. All from the base of the Coniston Flags. (Original.)

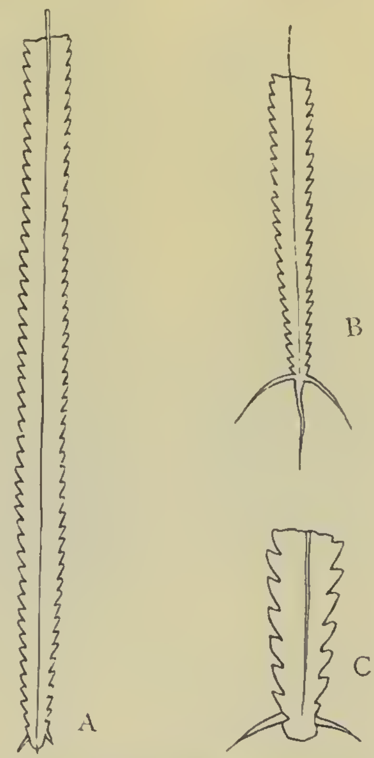

Fig. 84.—Diprionidian Graptolites (Original). A, A double-celled Graptolite (*Diplograptus*) with a minute basal spine ("sicula") and two lateral spines; B, Another form with a long sicula and two long lateral spines; C, Another form, in which the sicula is not visible.

As regards their distribution in time, the typical Graptolites are characteristic of the Ordovician and Silurian rocks. The diprionidian Graptolites (*e.g.*, *Diplograptus* and *Climacograptus*) are especially characteristic of the Ordovician and of the base of the Silurian formation. The common "twin" Graptolites (*Didymograptus*) are exclusively confined to the Ordovician formation. The fossils called *Dendrograptus*, *Callograptus*, *Ptilograptus*, and *Dictyonema*, though usually placed among the Graptolites, are possibly referable to the Sertularians. As regards their mode of occurrence, Graptolites are usually found as glistening pyritous impressions, with a silvery lustre; but they are sometimes found in relief.

CHAPTER XI.

HYDROCORALLINÆ AND STROMATOPOROIDEA.

HYDROCORALLINÆ.

SUB-CLASS V. HYDROCORALLINÆ.—This name has recently been proposed by Professor Moseley for two groups of marine animals which produce a regular skeleton of carbonate of lime, often of large size, and which have been generally referred to the Corals (*Actinozoa*). One of these groups comprises the well-known *Millepora* (fig. 85), which is found contributing so largely to the formation of coral-reefs in the West Indies and Pacific. The calcareous skeleton ("cœnosteum") of *Millepora*

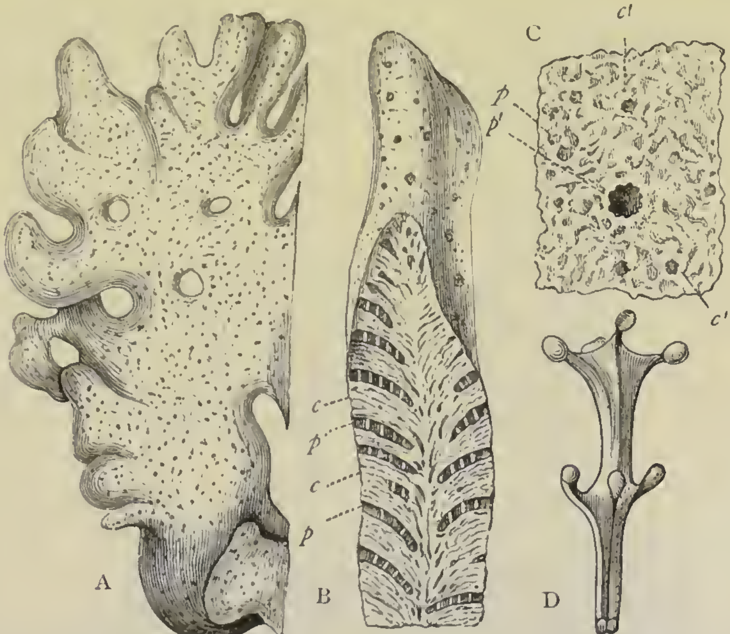

Fig. 85.—A, Portion of a mass of *Millepora alcicornis*, of the natural size; B, Portion of the same, cut open vertically to show the larger tabulate tubes (*p p*), and the spongy cœnosarcal skeleton (*c c*), enlarged; C, Small portion of the surface, enlarged to show the larger and smaller openings (*p'* and *c'*) inhabited by the different zoöids, and the reticulated calcareous tissue of the skeleton; D, One of the tentacular polypites, enlarged, showing two whorls of knobbed tentacles. (A, B, and C are after Milne-Edwards and Haime; D is after Martin Duncan and Major-General Nelson.)

is mostly in the form of foliaceous or laminar expansions, stony in texture, with a smooth surface studded with minute apertures of two sizes, the larger of these being much the fewest (fig. 85, C). The larger openings are the mouths of tubes (fig. 85, B, *p p*), which are divided by transverse calcareous partitions into a number of compartments, only the

most superficial of these being actually tenanted by the living animal. The smaller tubes are similarly septate or "tabulate," and the general tissue of the skeleton (fig. 85, C) is composed of calcareous trabeculæ traversed by a series of ramifying and anastomosing cœnosarcal canals, which place the tubes occupied by the zoöids in direct communication.

From the presence of transverse partitions, or "tabulæ," in its tubes, *Millepora* was generally placed amongst the so-called "Tabulate Corals," with the typical forms of which it has no affinity. Though its skeleton is abundantly obtained in the regions where it occurs, the living animal has been rarely observed. The late Professor Agassiz was the first to examine *Millepora* in its living condition, and he was led to the conclusion that the genus was unequivocally referable to the *Hydrozoa*. A similar conclusion has recently been reached by Professor Moseley, who had the opportunity of examining the living animal minutely. According to this observer, the colony (fig. 86) of *Millepora* consists of two kinds of zoöids.

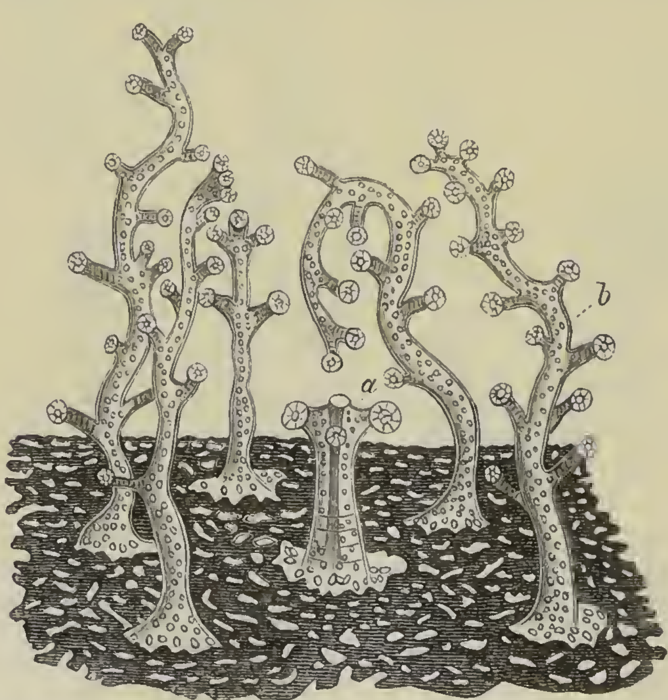

Fig. 86.—Enlarged view of a portion of the surface of a living colony of *Millepora nodosa*, showing the expanded zoöids of a single system : *a* Central "gastrozoöid"; *b* One of the mouthless "dactylozoöids." (After Moseley.)

The larger zoöids, "gastrozoöids," inhabit the larger tubes of the skeleton, and possess from four to six knobbed tentacles; while the smaller zoöids, or "dactylozoöids," inhabit the

smaller tubes, and are either indiscriminately mixed with the gastrozoöids, or surround these in definite systems (fig. 86, *a* and *b*). The dactylozoöids have no mouth, and are long and slender, carrying on their sides numerous short clavate tentacles. They perform the functions of prehension for the colony, and supply food to the stomach-bearing gastrozoöids, by which the work of digestion and assimilation is carried on. The nutritive fluid elaborated by the latter is distributed throughout the entire colony by means of branched cœnosarcal canals, which ramify in every direction through the spongy tissue of the skeleton.

The reproductive process is still unknown as regards the *Milleporæ* generally; but the reproductive elements are doubtless matured in special generative zoöids. Indeed, Mr Quelch has recently discovered in the skeleton of one species of *Millepora* the special sac-like cavities ("ampullæ") in which the reproductive zoöids are lodged. The species of *Millepora* are abundant in the shallow seas of the "coral-reef region," and especially so in the Pacific and West Indies. They often contribute largely to the growth of coral-reefs. Fossil forms have been detected in the Tertiary rocks.

Still more remarkable than the *Milleporæ* are the singular organisms forming the family of the *Stylasteridæ*, which have hitherto been regarded as Corals, but which have been shown by Professor Moseley to belong to the *Hydrocorallinæ*. The skeleton of the *Stylasteridæ* (fig. 87) is calcareous, more or less branched, forming a dendroid or flabellate expansion, and exhibiting upon the surface, or on its sides, small rounded apertures, which are usually intersected marginally by radiating partitions or "septa," and thus simulate the "calices" of an ordinary sclerodermic coral. In other cases, the skeleton shows a series of large apertures, with more numerous and irregularly distributed smaller openings, the latter not being radially arranged round the former. In any case, the skeleton is traversed in all directions by a system of branched and anastomosing canals, which are occupied in the living condition by prolongations of the cœnosarc, which also forms an ectodermal covering to the skeleton. The colony is composed of two different sets of zoöids—those of the one set ("gastrozoöids") provided with a mouth and stomach-sac; while the others ("dactylozoöids") are elongated and destitute of a mouth, thus coming to represent tentacles in form. The gastrozoöids occupy, as in *Millepora*, the large tubes of the skeleton, and the dactylozoöids are lodged in the small tubes. Hence, when the dactylozoöids are arranged in definite

"cyclo-systems" round the gastrozoöids, then each of the large apertures in the skeleton comes to be surrounded by a circle of smaller elongated pores, which are only separated laterally by thin partitions, and which thus give rise to the appearance of a central "calice" surrounded by radiated "septa" (fig. 87, B). The gastrozoöids are not only larger than the dac-

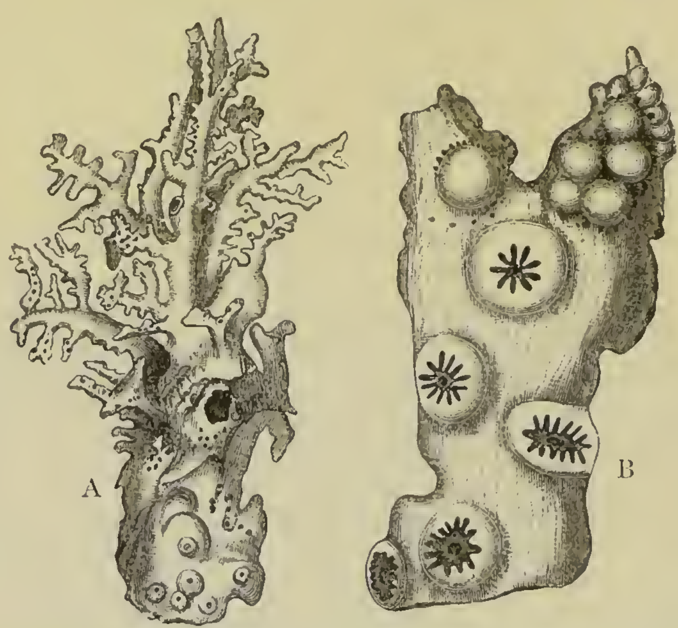

Fig. 87.—A, Portion of the skeleton of *Stylaster sanguineus*, of the natural size; B, Small portion of a branch of the same, enlarged, showing the calices and ampullæ. Living in the Australian Seas. (After Milne-Edwards and Haime.)

tylozoöids, but they have a special layer of digestive cells lining the body-cavity, a structure which is wanting in the purely prehensile dactylozoöids. The true Hydrozoal character of these extraordinary organisms is conclusively shown by the fact that the reproductive organs are situated outside the bodies of the ordinary zoöids, being in the form of fixed sporosacs developed within sac-like cavities ("ampullæ") in the skeleton (fig. 87, B), which at certain periods communicate with the exterior by minute pores.

The Stylasterids are wholly marine, and are almost cosmopolitan in their distribution, the species ranging from the neighbourhood of the coast-line to great depths in the ocean.

Stromatoporoidea.

Sub-class VI. Stromatoporoidea.—Under this head are included a large number of extinct organisms, the skeletons of

which are of common occurrence in the older rocks of the earth's crust. The Stromatoporoids possessed a calcareous skeleton ("cœnosteum"), the most marked general feature of which is that it is more or less conspicuously composed of concentric calcareous laminæ (fig. 88). The skeleton was often

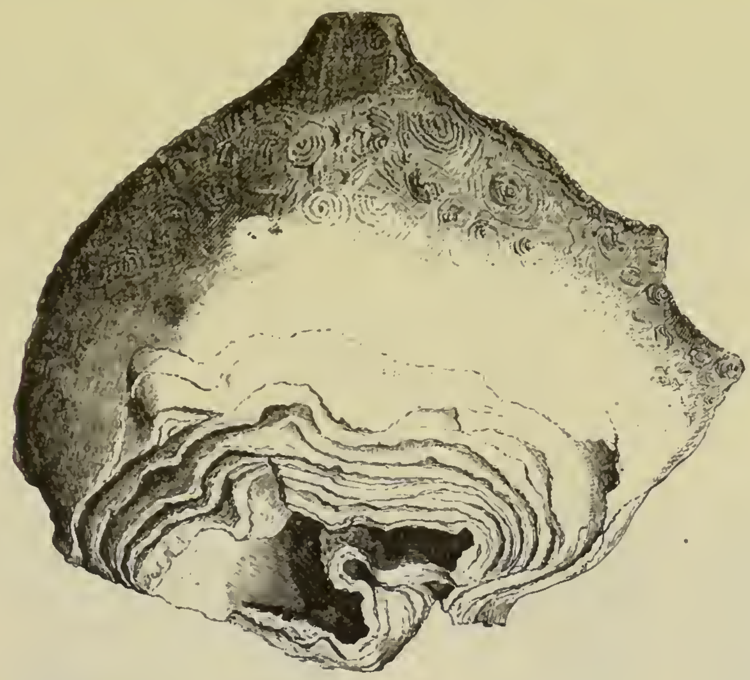

Fig. 88.—A Stromatoporoid, of the natural size, showing the laminated structure of the skeleton. Trenton Limestone, Canada.

of great size, and the under surface was often covered by a delicate calcareous membrane ("epitheca"), the organism being fixed to some foreign body by a stalk of attachment. In other cases the organism was encrusting, the entire lower surface being attached to some foreign body; while other types are branched. In the genus *Stromatopora* itself, the skeleton is composed of closely reticulated calcareous fibres, which have a peculiar minutely porous or tubulated structure, and which admit of division into a horizontal and a vertical series, fused with one another. The entire skeleton is traversed by minute irregular tubes, which are commonly crossed by transverse partitions ("tabulæ"), and which open on the surface by small pores. These tubes undoubtedly served for the lodgment of the zoöids of the colony. There is thus a general resemblance in the skeleton of *Stromatopora* to that of *Millepora;* but the zoöidal tubes do not exhibit a division into a

series of large tubes and one of small tubes; while there are other differences as well which need not be discussed here.

In other types of the Stromatoporoids (such as *Actinostroma*), the structure of the skeleton approaches more nearly to that of *Hydractinia* than to that of *Millepora*.

The typical Stromatoporoids are, so far as is certainly known at present, confined to the Ordovician, Silurian, and Devonian formations, in which they are often so abundant as to give rise to extensive beds of limestone. In the Secondary rocks occur various fossils, which will possibly find a place here when fully investigated; but the group is not known to have any direct representative in the Tertiary rocks or in modern seas.

CHAPTER XII.

ACTINOZOA.

1. General Characters of the Actinozoa. 2. Characters of the Zoantharia. 3. Zoantharia Malacodermata. 4. Zoantharia Sclerobasica. 5. Zoantharia Sclerodermata.

Class II. Actinozoa.—The *Actinozoa* are defined as *Cœlenterata in which the mouth opens into an œsophageal tube, which in turn opens below into the general cavity of the body* (" *cœlenteric space*.") *The œsophagus is separated from the body-wall by an intervening* "*perivisceral space*," *which is divided into a series of compartments by radiating vertical membranous partitions or* " *mesenteries*," *to the faces of which the reproductive organs are attached.*

The *Actinozoa* differ, therefore, fundamentally from the *Hydrozoa* in this, that whereas in the latter the space ("cœlenteric" space) included within the body-walls is simple and undivided, and there is no proper alimentary tube, in the former there is a distinct œsophagus (fig. 89, *b*), and the general cavity of the body is divided into radial compartments by vertical membranous plates ("mesenteries"). Hence in transverse sections (if taken above the level of the lower end of the œsophagus) there are seen two concentric tubes, one formed by the œsophagus, and the other by the parietes of the body (fig. 90, A); whereas the transverse section of

a Hydrozoön exhibits but a single tube formed by the general walls of the body.

Histologically, the tissues of the *Actinozoa* are essentially the same as those of the *Hydrozoa*, consisting of the two fundamental layers, the "ectoderm" and "endoderm." Between these there is developed an intermediate layer or "mesoderm," composed essentially of connective tissue. The tissues of the *Actinozoa* often exhibit a considerable amount of differentiation, but this subject has been already sufficiently considered in dealing with the *Cœlenterata* generally (see p. 126, fig. 50).

The mouth in the *Actinozoa* opens into a membranous œsophageal tube, formed by an infolding of the ectoderm and endoderm, which hangs down into the body-cavity, and terminates at some distance above the proximal end of the animal in an aperture by which it communicates with the general cavity of the body (fig. 89, *b*). Though often spoken of

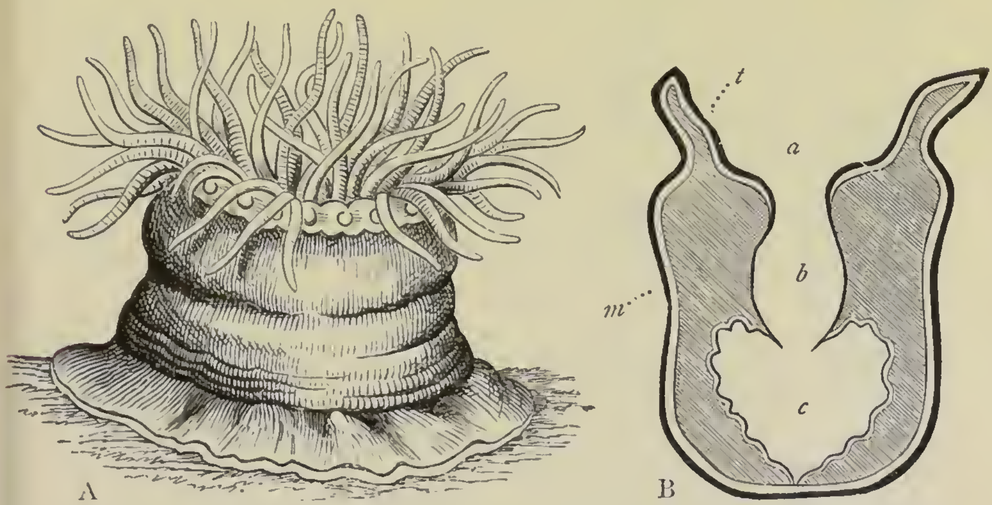

Fig. 89.—A, *Actinia mesembryanthemum*, one of the Sea-anemones (after Johnston); B, Section of the same, showing the mouth (*a*), the œsophagus (*b*), the body-cavity (*c*), and one of the mesenteries (*m*).

as the "stomach," it does not appear that the œsophageal tube has any special digestive power, the function of digestion being performed by the general body-cavity. There is no proper vascular system, but the fluid filling the body-cavity contains the products of digestion, and therefore corresponds with the blood, while a circulation of this fluid is kept up by the ciliated surface of the endoderm. Proper respiratory organs are not developed, though some forms possess structures which are believed to have a respiratory function.

The general space included within the body-walls is subdivided into radiating compartments by the so-called "mesenteries." Below the level of the lower end of the œsophagus the intermesenteric compartments all open freely into a common space (fig. 89, B, *c*). These compartments also commonly communicate with one another by means of perforations in their bounding mesenteries placed near the point where the latter join the upper end of the œsophagus.

The nervous system is typically in the form of a layer of detached ganglionic cells and diffused fibres placed beneath the ectoderm (fig. 50, B), similar nervous elements being also developed more sparingly at the base of the endodermal layer. The pigment-masses which are found at the bases of tentacles in some *Actiniæ* are possibly rudimentary organs of vision.

The reproductive organs are always internal, and are never in the form of external processes as in the *Hydrozoa*. They have the form of band-like ovaria or testes attached to the faces of the mesenteries. Sexual reproduction occurs in all the members of the class, but in many forms gemmation or fission constitutes an equally common mode of increase. Some *Actinozoa*, therefore, such as the common Sea-anemones, are simple organisms; whilst others, such as the reef-building corals, are composite, the act of gemmation or fission giving rise to colonies composed of numerous zoöids united by a cœnosarc. In these cases the separate zoöids are termed "polypes," the term "polypite" being restricted to the *Hydrozoa*. In the simple *Actinozoa*, however, the term "polype" is employed to designate the entire organism. In other words, the "actinosoma," or entire body of any *Actinozoön*, may be composed of a single "polype," or of several such, produced by a process of continuous gemmation or fission, and united by a common connecting structure, or cœnosarc. In certain cases (*Fungia*) there is a kind of alternation of generations.

Most of the *Actinozoa* are permanently fixed; some, like the Sea-anemones, possess a small amount of locomotive power; and one order, the *Ctenophora*, is composed of highly active, free-swimming organisms. Some of the *Actinozoa* are unprovided with any hard structure or support, as in the Sea-anemones and in all the *Ctenophora;* but a large number secrete a calcareous or horny, or partially calcareous and partially horny, framework or skeleton, which is termed the "coral," or "corallum."

The *Actinozoa* are divided into four orders—viz., the *Zo-*

antharia, the *Alcyonaria*, the *Rugosa*, and the *Ctenophora*; but the last is sometimes regarded as a distinct class, and the *Rugosa* are doubtfully separable as an order from the *Zoantharia*.

ORDER I. ZOANTHARIA.—The *Zoantharia*, *Hexacoralla*, or "Helianthoid Polypes," are defined *by the disposition of their soft parts* (*typically*) *in multiples of six*, *and by the possession of simple*, *usually numerous*, *tentacles. There may be no corallum, or rarely a "sclerobasic" one. Usually there is a "sclerodermic" corallum*, *in which the septa in each corallite*, *like the mesenteries*, *are arranged in multiples of six.*

The above characters, though distinctive of the *Zoantharia* as an order, are not capable of universal application, since the disposition of the mesenteries in sixes cannot be always recognised, and the tentacles are in rare instances fringed with lateral processes ("pinnate").

The *Zoantharia* are divided into three sub-orders—the *Zoantharia malacodermata*, the *Z. sclerobasica*, and the *Z. sclerodermata*; according as the corallum is entirely absent or very rudimentary, is "sclerobasic," or is "sclerodermic."

SUB-ORDER I. ZOANTHARIA MALACODERMATA.—In this section of the *Zoantharia* there is either no corallum or a pseudo-corallum in the form of adventitious spicules scattered through the soft parts. The "actinosoma" is usually composed of but a single polype. (The term "actinosoma" is a very convenient one to express in the *Actinozoa* what "hydrosoma" expresses in the *Hydrozoa*—namely, the entire organism, whether simple or compound.)

This section has been divided into many groups, of which only the ordinary Sea-anemones (*Hexactiniæ*) can receive any detailed consideration here.

The body of a Sea-anemone (fig. 89, A) is a truncated cone, or a short cylinder, termed the "column," and is of a soft, leathery consistence. The two extremities of the column are termed respectively the "base" (or "pedal disc") and the "oral disc," the former constituting the sucker, whereby the animal attaches itself at will, whilst the mouth is situated in the centre of the latter. Most Sea-anemones fix themselves by the base to some foreign object—a stone or a living animal—but others (*Peachia* and *Edwardsia*) bury themselves more or less completely in the sand. In a few cases (*Cerianthus* and *Peachia*) the centre of the base is perforated, but the object of this arrangement is unknown. Some forms, again (*Minyas*, *Nautactis*, *Oceanactis*, &c.), are oceanic in their habit. Between the mouth and the circumference of the disc is a flat

space, without appendages of any kind (or, rarely, with a circlet of secondary tentacles), termed the "peristomial space." Round the circumference of the disc are placed numerous tentacles, usually retractile, arranged in alternating rows. The tentacles are tubular prolongations of the ectoderm and endoderm, containing diverticula from the somatic chambers, and often having apertures at their free extremities. The mouth leads directly into the œsophagus, which is a wide membranous tube, opening by a large aperture into the general body-cavity below, and extending about half-way between the mouth and the base. The mouth is typically a longitudinal fissure, the direction of which is constant, thus giving a middle line to the radiated body. The œsophagus (fig. 90, A, *s*) conforms in shape with the mouth, being long-

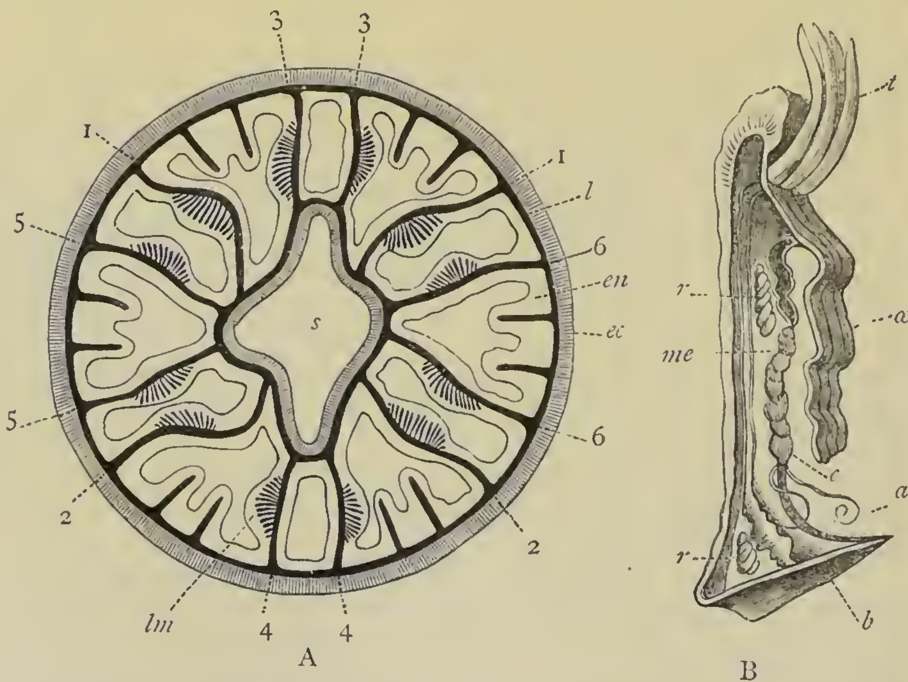

Fig. 90.—A, Transverse section of a Sea-anemone (*Adamsia*), slightly altered from O. and R. Hertwig: *ec* The ectoderm (cross-shaded); *l* The mesodermal layer of connective-tissue (shaded dark); *en* The endoderm (unshaded); *lm* Cross-section of one of the longitudinal septal muscles; *s* Œsophagus. The numerals indicate the order of development of the six principal pairs of septa, the third and fourth pairs being the so-called "directive septa." B, A segment of the body of a Sea-anemone (*Cereus*), traversing the column from the base to the disc (after R. Hertwig): *b* Disc; *t* Tentacles; *æ* Œsophagus hanging down into the body-cavity; *r r* Reproductive organs attached to the faces of the mesenteries; *c* One of the "craspeda"; *a* One of the "acontia"; *me* Mesenteries.

oval, and usually having a deep longitudinal groove at the ends corresponding with the long axis of the mouth-opening.

The wide space between the œsophagus and the body-wall is subdivided into a number of compartments by radiating vertical lamellæ, which are formed of connective-tissue covered on each side with endoderm (fig. 90, A), and which are termed the "mesenteries" or "septa." All the mesenteries spring along their outer sides for their whole length from the body-wall, and a certain number of them are continued across the whole perivisceral space, and are attached to the sides of the œsophagus. Besides these complete mesenteries, there are others (fig. 90, B, *me*) which do not reach so far as the outer surface of the œsophagus. As the œsophagus is considerably shorter than the column, it follows that the inner edges of even the longest mesenteries are free below the lower end of the gullet; and these free edges, curving at first outwards and then downwards and inwards, are ultimately attached to the centre of the base.

The mesenteries have attached to their faces the reproductive organs (fig. 90, B, *r*), in the form of band-like ovaries and testes. The same individual may have these organs combined; but more commonly the sexes are distinct. Below the stomach the free edges of the mesenteries are thickened, and constitute convoluted and puckered cords—the so-called "craspeda," or "mesenteric filaments" (fig. 90, B, *c*), which have a glandular structure, and are concerned in digestion. Attached also to the free edges of the mesenteries are sometimes long thread-like filaments, which contain many thread-cells, and are termed "acontia" (fig. 90, B, *a*). When at rest, the acontia lie coiled in the space below the gullet, but they can be protruded from the mouth, or can sometimes be shot forth from minute apertures ("cinclides") in the body-wall.

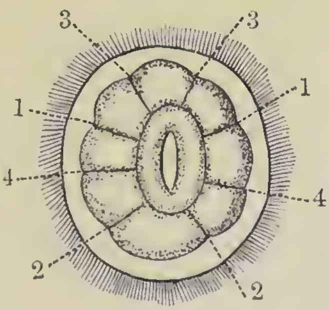

Fig. 91.—Embryo of a Sea-anemone (*Actinia mesembryanthemum*), in which the first eight septa have been developed (after Lacaze-Duthiers). The numerals indicate the order in which primitive septa make their appearance.

The embryo of the *Actiniæ* (fig. 91) is a free-swimming ciliated body, at first rounded, but afterwards somewhat ovate. The rudimentary mouth is soon marked out by a depression at the larger extremity; thread-cells appear as a layer in the ectoderm; a fold is prolonged inwards from the mouth to form the œsophageal tube; and the primitive tentacles are at first two in number, but are rapidly increased to six.

As regards the structure, arrangement, and development of the mesenteries of the *Actinidæ*, absolute uniformity does not obtain. Typically, each

mesentery consists of a plate of connective-tissue ("supporting-lamella") covered on each side with endoderm. On one side each mesentery carries a layer of transversely-directed muscular fibres; while on the opposite side of each is a well-defined longitudinal "retractor" muscle, which springs from the base and is inserted into the gullet or into the oral disc. The mesenteries are arranged *in pairs*, the corresponding muscles being turned in each pair towards each other. In all but two pairs of mesenteries, the sides which are in each pair turned to each other are the ones which carry the longitudinal muscles (fig. 90, A, *lm*). In two pairs of mesenteries, which are known as the "directive mesenteries," and which correspond in position with the extremities of the slit-like mouth, the sides which are turned to each other are those with the transverse muscles.

The mesenteries of each pair generally have a common origin, but this does not hold good for the first six pairs of mesenteries that are developed. These latter are produced independently and at different times, and are termed by R. Hertwig the "principal mesenteries." The two pairs of "directive mesenteries" belong to this series; and in some cases (*e.g.*, in *Sagartia*) it is only these six pairs of "principal mesenteries" which reach the outer wall of the œsophagus. The remaining mesenteries, excluding the six pairs just mentioned, are termed by Hertwig the "secondary" mesenteries, and these may or may not in part reach the wall of the œsophagus. (In many works the terms "primary," "secondary," and "tertiary" have been used to express the fact that the mesenteries reached the œsophagus, or to indicate their comparative width if they fell short of it; but the distinction above pointed out is one of greater importance.)

As regards the early development of the mesenteries, Lacaze-Duthiers has shown that the first step is the appearance of a single pair of mesenteries developed at right angles to the oral fissure, nearer one side than the other, so as to divide the body-cavity into two unequal chambers (fig. 91, 1, 1). In the larger of these chambers appear the two next mesenteries (2, 2), one on each side. Two additional mesenteries (3, 3) next appear in the smaller chamber, this making in all *six* mesenteries; but this condition is evanescent, and two further septa (4, 4) are developed on the opposite side of the first-formed mesenteries to the third pair. At this stage, therefore, there are *eight* mesenteries in all (fig. 91); but two further pairs of mesenteries are produced, raising the number to *twelve*, and completing the series of the "principal" mesenteries. The next twelve mesenteries are developed in pairs in the interspaces between the six pairs of "principal" mesenteries ("interseptal spaces"), this condition being shown in fig. 90, A. No fresh mesenteries are, however, produced in the chambers ("intraseptal spaces") included between the laminæ which form each pair of "principal" mesenteries.

In certain Sea-anemones (united by Hertwig into the group of the *Paractiniæ*) the number of the mesenteries is not regulated by *six*, as is typically the case, but by *four*. A similar tetramerous arrangement of the mesenteries obtains in the singular genus *Edwardsia* (fig. 92, A), in which only eight mesenteries are present. This singular form has a thin imperforate base, and lives buried to the lips in mud or sand, the middle part of the body being protected by an epidermic investment. *Cerianthus*, again, has the mesenteries unpaired, and has a pore in the base. It also lives buried in the sand, and has

the body protected by a curious membranous tube, with sand-grains disseminated in it. Another curious group of the Sea-anemones is that of the *Ilyanthidæ*, which have the base rounded and non-adherent. The type of this group is *Ilyanthus* itself (fig. 92, B), which, except for the condition of its

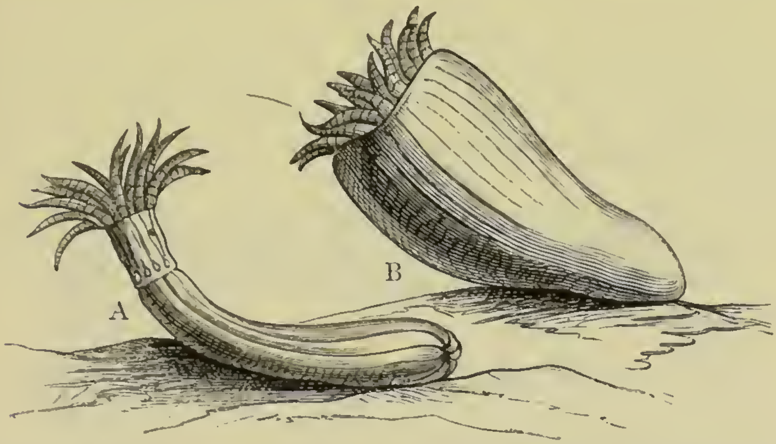

Fig. 92.—A, *Edwardsia callimorpha*; B, *Ilyanthus Mitchelli*, of the natural size. (After Gosse.)

base, is allied to the ordinary Sea-anemones. Lastly, in the group of the *Zoanthidæ* the actinosoma is compound, and consists of polypes connected by a fleshy crust, or by hollow creeping cœnosarcal prolongations. The walls of the polypes are usually strengthened by a membranous crust, in which sand-grains and other adventitious bodies, or sometimes calcareous spicules, are embedded. Examples of this family are *Zoanthus* and *Palythoa*.

As regards their *distribution in space*, the *Zoantharia malacodermata* appear to have an almost cosmopolitan range, Sea-anemones being found on almost every coast—some of the tropical forms attaining a very large size. Whilst essentially littoral and shallow-water forms, a few of the members of this group have been found by the Challenger expedition to extend to great depths. Thus, as shown by Professor Moseley, *Edwardsia* has been found at 800 fathoms, and *Cerianthus* at no less than 2750 fathoms; while species of *Actinia* itself go down to over 1000 fathoms. A few forms also (such as *Arachnactis*, *Nautactis*, *Plotactis*, *Oceanactis*, and *Minyas*) are pelagic in habit, and live in the open ocean.

SUB-ORDER II. ZOANTHARIA SCLEROBASICA.—The "Black Corals" or *Antipathidæ*, which compose this group, are always *composite, consisting of a number of polypes united by a thin*

fleshy cœnosarc, which is spread over and supported by a simple or more commonly branched horny axis or "sclerobase." The tissues are not furnished with calcareous secretions, and the polypes have in general six simple tentacles.

The corallum or skeleton of the *Antipathidæ* is of a horny consistence, its form simple or branched in a more or less complicated and plant-like manner, and its surface smooth or covered with minute spines. All the *Antipathidæ* form colonies, which are rooted by the base to some foreign object, and which consist of numerous minute polypes united by a fleshy cœnosarc (fig. 93). The corallum is secreted by the *cœnosarc*,

Fig. 93.—Part of the living stem of *Antipathes anguina*, of the natural size. (After Dana.)

and thus forms an *axis* or stem which is completely covered during life by the soft parts of the colony, just as the trunk of a tree is covered by the bark. Owing, further, to the fact that the skeleton is produced by the cœnosarc, the corallum is wholly outside the polypes, which are themselves altogether destitute of a coherent skeleton. Various other *Actinozoa* (such as the *Gorgonidæ*) possess, as we shall see, a similar axial skeleton, secreted by the cœnosarc; and all such coralla are said to be "sclerobasic." The *Antipathidæ* are principally inhabitants of warm seas, but they are found also in the Arctic ocean, and some forms range to great depths.

SUB-ORDER III. ZOANTHARIA SCLERODERMATA OR MADREPORARIA.—The members of this sub-order include the great bulk of the coral-producing or "coralligenous" zoophytes (*Madreporaria*) of recent seas. They are defined by the possession of *a corallum which is partially or wholly developed within the tissues of the polypes themselves* ("*sclerodermic*"), *which does not consist simply of scattered spicules, and in which the parts are very generally disposed in multiples of six. The actinosoma may be simple, consisting of a single polype only, or composite, consisting of many polypes united by a cœnosarc.*

As regards the anatomy of their soft parts, the simple *Zoantharia sclerodermata* may be regarded as essentially Sea-anemones, whilst the compound forms are simply colonies of Actinioid polypes united by a common flesh or cœnosarc. It is therefore only necessary to consider the nature of the skeleton

or corallum of these forms, since the leading peculiarities of the sub-order are to be found in this.

If we examine first a simple coral of this group, we find that we have to deal with an animal in all important respects identical with an ordinary Sea-anemone, but having a more or less complicated skeleton developed in its interior. The animal possesses a base, a column, and a disc—the latter surrounded by tentacles, and perforated centrally by the mouth. The mouth opens into an œsophageal tube, connected with the body-walls by mesenteries; and the tentaculate disc and dependent gullet remain permanently soft and capable of contraction and expansion. Below the gullet, the soft tissues of the polype are strengthened and supported by a more or less perfect calcareous skeleton or corallum (fig. 94).

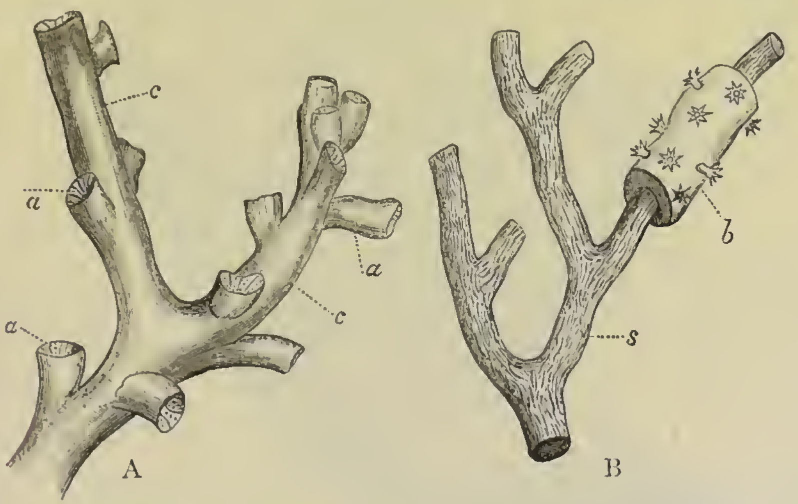

Fig. 94.—Sclerodermic and sclerobasic Corals. A, Branch of *Dendrophyllia nigrescens*, a sclerodermic coral, showing the cups or thecæ (*a a*) secreted by the separate polypes, and united by the cœnenchyma (*c c*). B, Portion of a sclerobasic coral (*Gorgonia*) represented diagrammatically: *s* The solid and branched sclerobase; *b* A portion of the soft cœnosarc with its embedded polypes, investing the sclerobasic axis.

This is composed of calcareous matter ("sclerenchyma") deposited by the tissues in such a way that the corallum comes to lie *within the polype*, and is technically said to be "sclerodermic." The "sclerodermic" corallum is therefore the result of the secretion of lime by the actual polypes, and thus differs from the "sclerobasis" of the *Antipathidæ* and *Gorgonidæ*, which is secreted by the cœnosarc, and is not formed by a calcification of the soft parts of the polypes themselves. The general distinction, arising from their mode of formation, between "sclerobasic" and "sclerodermic" corals, is not perhaps of essential importance, and the

boundary-line between the two is not very clearly marked; but it is of considerable practical value. It is, moreover, a distinction which is readily recognised, as a rule, by a simple inspection of the corallum itself. A sclerobasic corallum, namely, being secreted solely by the cœnosarc, never exhibits any parts which correspond with the separate polypes of the colony. On the other hand, the sclerodermic corallum (when not composed simply of scattered spicules) either consists of a single cup-like structure corresponding with a single polype (fig. 95), or of several such (fig. 94, A) united by a common skeleton.

A typical simple sclerodermic corallum (fig. 95) is secreted

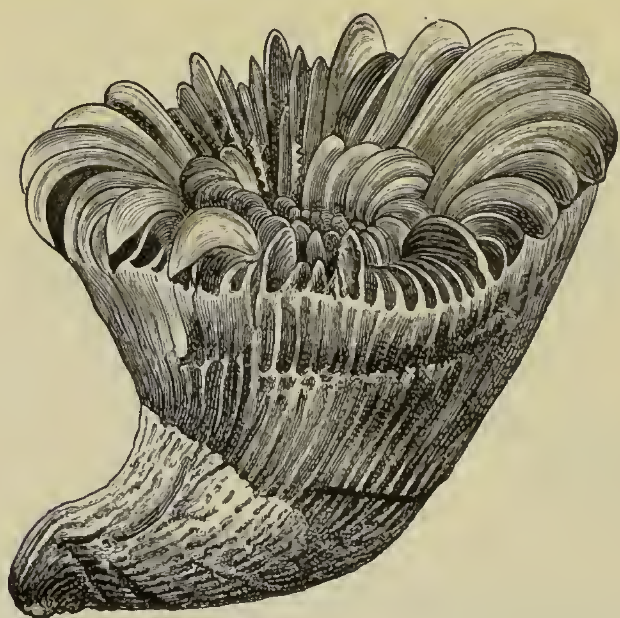

Fig. 95.—*Caryophyllia borealis.* A simple sclerodermic Coral, twice the natural size. (After Sir Wyville Thomson.)

by a single polype, and its structure presents an obvious correspondence with that of the animal which produces it. It is generally more or less conical in shape, sometimes discoid, consisting of an outer wall and included space. The wall corresponds with the lower part of the column of the polype, and is known as the "theca." It may be very imperfect, or may be strengthened by a secondary calcareous investment ("epitheca"). The theca encloses a space which corresponds with the lower part of the body-cavity of the polype, and is known as the "visceral chamber." Superiorly the theca terminates in a shallower or deeper cup-shaped depression, which

contains the œsophagus of the polype, and is known as the "calice." Below the calice, the visceral chamber is subdivided into a number of vertical compartments ("loculi") by a series of upright partitions or "septa," which spring from the inner surface of the theca, and are directed inwards towards the centre. The septa are calcifications formed within the intermesenteric chambers (fig. 96, *s*), so that each septum is placed underneath a tentacle, and the total number of the septa is equal to that of the mesenteries. The septa likewise increase in number with the increasing growth of the polype, as the mesenteries do; and, like the latter, they vary in their width, so that they are often spoken of as "primary," "secondary," and "tertiary" septa.

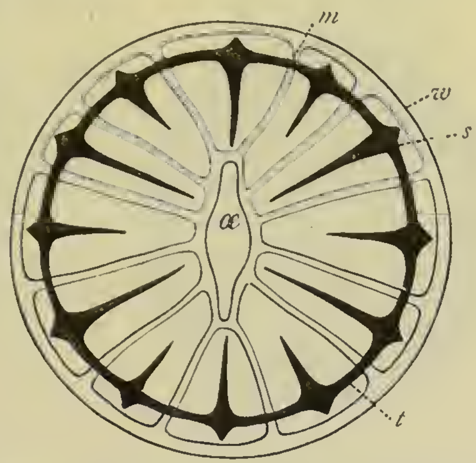

Fig. 96.—Cross-section of a simple Coral (*Caryophyllia*) diagrammatically represented (altered from a figure by von Koch). *w* Body-wall of the polype; *m* One of the twelve principal mesenteries; *s* One of the primary septa; *t* Theca of the corallum, formed by the union of the outer ends of the septa; *æ* Œsophagus of the polype.

It has been generally stated that the theca is the result of the calcification of the body-wall of the polype, and that the septa are produced by the calcification of the mesenteries. Von Koch, however, has shown that in many corals the body-wall really lies quite external to the theca, and that the latter is formed by the thickening and ultimate fusion of the outer ends of the septa. Moreover, it has been shown by Lacaze-Duthiers that the septa are not produced in the mesenteries themselves, but in the intermesenteric chambers. From the researches of this observer, it would appear that the formation of the corallum begins by the deposition of lime in the ectoderm of the base or pedal disc of the polype, giving rise to a calcareous plate ("foot-plate") by which the coral is usually fixed to some foreign body. The septa are developed as radiating ridges from the upper surface of this foot-plate, and they grow upwards into the intermesenteric chambers as vertical lamellæ, which are covered internally by the endoderm. The theca is produced subsequently to the septa, and, as above mentioned, is often, if not always, formed by the coalescence of the outer ends of the septa in the course of growth.

The septa in the adult sclerodermic corallum are typically some multiple of six in number, arranged in six systems; but this rule is not of universal application, and the typical hexameral arrangement may be departed from altogether. The laws of development of the septa are complicated, and need

not be discussed here. On the outside of the theca are vertical ridges ("costæ"), corresponding with the septa within; and the centre of the visceral chamber may be vacant, or may be occupied by an axial rod-like or spongy structure, which is termed the "columella." At the inner ends of the septa may be developed narrow vertical plates which are known as "pali" (fig. 97, *p*). The continuity of the "interseptal loculi" is

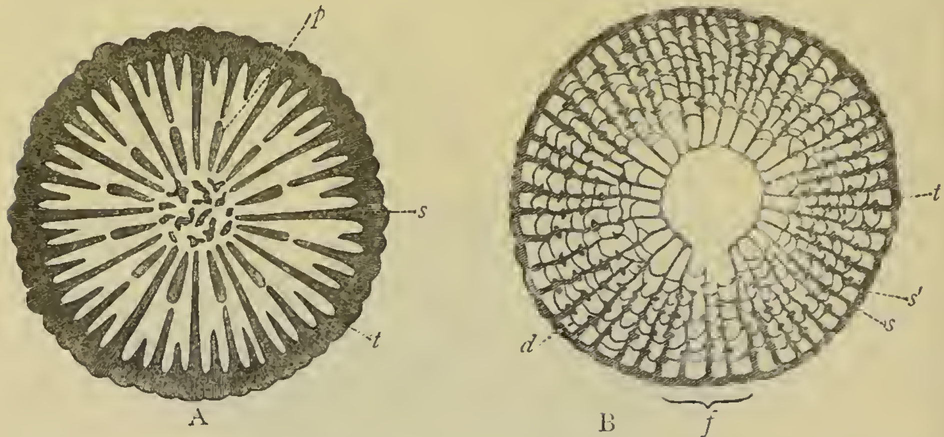

Fig. 97.—A, Transverse section of a simple Zoantharian Coral (*Cyathina Bowerbanki*), enlarged. (After Milne-Edwards and Haime.) *t* Theca; *s* One of the primary septa; *p* One of the "pali." In the centre is seen the irregular "columella." B, Tranverse section of a Rugose coral (*Crepidophyllum subcæspitosum*), enlarged four times (Original). *t* Theca; *d* "Dissepiments"; *s* One of the first order of septa; *s'* One of the second order of septa; *f* "Fossula." In the centre of the coral is a space occupied by tabulæ.

liable to be more or less interfered with by the development of the structures known as "synapticulæ," "dissepiments," and "tabulæ." The "synapticulæ" are transverse calcareous bars which stretch across the interseptal loculi, and form a kind of trellis-work, uniting the opposite faces of adjacent septa. They are characteristic of the *Fungidæ*. The "dissepiments" are commonly present in a great many corals, and have the form of incomplete, approximately horizontal plates, which stretch between adjacent septa, and break up the interseptal loculi into secondary compartments or cells. Lastly, the "tabulæ" may be regarded as highly developed dissepiments, and, like them, are approximately horizontal, as a rule at any rate. They differ from the dissepiments in the fact that they cut across the interseptal loculi at the same level. When fully developed (fig. 98, D), they are transverse plates, which extend completely across the visceral chamber, and divide it into a series of storeys placed one above the other, the only living portion of the coral being above the last-formed tabula.

Tabulæ are found in various of the *Zoantharia sclerodermata*, in some of the *Alcyonaria*, and in a great many of the *Rugosa*.

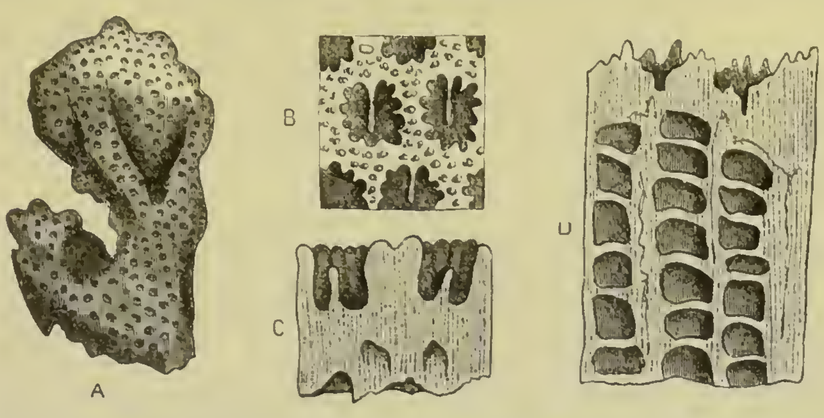

Fig. 98.—A, Portion of the corallum of *Pocillopora aspera*, var. *lata*, Verrill, of the natural size. B, Part of the surface of same, enlarged. C, Section of the corallites of the same, showing the columella, enlarged. D, Vertical section of the same, enlarged, showing tabulæ. (After Dana.)

The above gives the general structure of a typical simple sclerodermic corallum, as secreted by a single polype. A *compound* sclerodermic corallum is the aggregate skeleton produced by a colony of such polypes, and varies in form and size according to the characters of the colony by which it is produced. In general, such a colony consists (fig. 99) of a

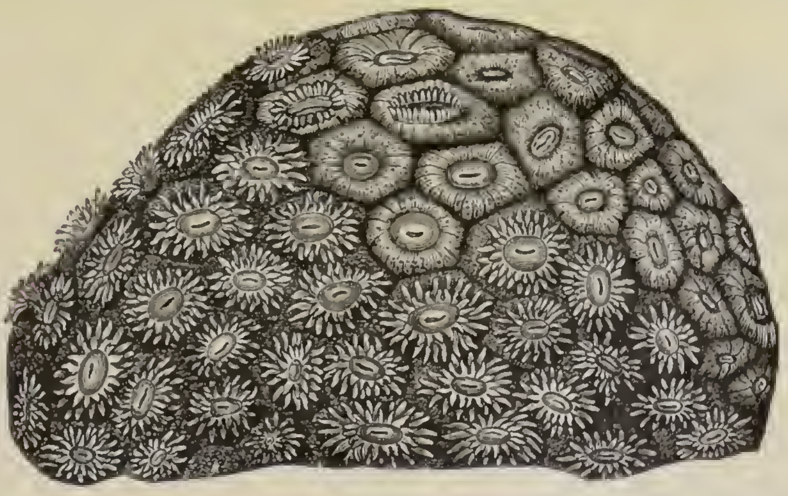

Fig. 99.—*Astræa pallida*, a compound sclerodermic Coral, in its living condition. (After Dana.)

number of polypes, which may spring directly from one another, or may be united by a common flesh or cœnosarc; and corresponding elements are found in the corallum. In the

former instance, the compound corallum consists of an assemblage of separate "corallites," as the skeletons of the individual polypes are called, these being united with one another directly and in various ways. In the latter instance, the corallum consists of a number of "corallites" and of a common calcareous basis or tissue, which unites the various corallites into a whole, is secreted by the cœnosarc, and is known as the "cœnenchyma."

The compound coralla are, of course, primitively simple, and they become composite either by budding or by cleavage of the original polype. The following are the principal methods in which the increase is effected; and in considering this subject briefly, it will be as well to take into account not only the *Zoantharia sclerodermata*, but also the *Rugosa*, the modes of increase in the two groups being very similar: (1.) *Lateral* or *parietal gemmation.*—In this mode of increase the original polype throws out buds from some point on its sides between the base and the circle of tentacles, and these buds on becoming perfect corallites may repeat the process. This is one of the commonest modes of growth amongst the recent corals, and it gives rise chiefly to dendroid or tree-like corals.

(2.) *Basal gemmation.*—In this method the original polype gives forth from its base a rudimentary cœnosarc, from which new buds are thrown up, and which may have the form of foot-like prolongations or of a continuous horizontal expansion. The resulting coralla are usually massive or encrusting, and the youngest corallites are, of course, those placed on the periphery of the colony.

(3.) *Calicular gemmation.*—This consists in the production of buds from the calicine disc of the parent corallite, which may or may not continue to grow thereafter, whilst the new corallites thus produced generally repeat the process. This mode of growth is exceedingly rare amongst the *Zoantharia sclerodermata*, and is never typically exhibited; but it is a characteristic feature in many of the *Rugose* corals. In many of these (fig. 100) the original polype throws up from its calicine disc one or more new corallites, which kill the parent. These, in turn, produce others after a similar fashion, till the entire corallum assumes the form of an inverted pyramidal mass resting upon the original budding polype. In other *Rugose* corals the calicine disc gives off but a single bud, which may repeat the process indefinitely till the corallum presents the appearance of a succession of inverted cones placed one above the other.

Fig. 100.—Calicular gemmation as seen in *Lonsdaleia floriformis*. Carboniferous.

(4.) *Fission.*—This process in the coralligenous *Actinozoa* is usually effected by "oral cleavage," the divisional groove commencing at the oral disc, and deepening to a greater or less extent, the proximal extremity always remaining undivided. According to Dana, in fission a new mouth is formed in the disc near the old mouth, and a new

gullet is formed for the new mouth, round which the new tentacles are then developed. This, therefore, is not, strictly speaking, a subdivision into halves; since one half carries off the old mouth and gullet. More rarely, fission "is effected by the separation of small portions from the attached base of the primitive organism, whose form and structure they subsequently, by gradual development, tend to assume.

"The coral-structures which result from a repetition of the fissiparous process are of two principal kinds, according as they tend most to increase in a *vertical* or in a *horizontal* direction. In the first of these cases the corallum is *cæspitose*, or tufted, convex on its distal aspect, and resolvable into a succession of short diverging pairs of branches, each resulting from the division of a single corallite." In the second case the coral becomes *lamellar*. "Here the secondary corallites are united throughout their whole height, and disposed in a linear series, the entire mass presenting one continuous theca." Both these forms of corallum are "liable to become *massive* by the union of several rows or tufts of corallites throughout the whole or a portion of their height. An illustration of this is afforded by the large *gyrate* corallum of *Meandrina*, over the surface of whose spheroidal mass the calicine region of the combined corallites winds in so complex a manner as at once to suggest that resemblance to the convolutions of the brain which its popular name of Brain-stone Coral has been devised to indicate" (Greene).

The *Zoantharia sclerodermata* are divided into the three following groups, founded upon the characters of the corallum :—

1. *Aporosa.*—The calcareous tissue of the corallum is more or less compact and imperforate; the septa usually constituting complete solid plates, and the theca being as a rule not pierced by any apertures. Dissepiments or synapticulæ are usually present, but tabulæ are rarely developed. This section includes the most highly developed of existing corals (*Turbinolidæ*, *Oculinidæ*, *Astræidæ*, &c.)

2. *Fungida.*—The "Mushroom-corals" (*Fungidæ*) and a number of allied forms constitute a group of corals intermediate between the Aporose and Perforate types. The septa are usually imperforate, but the basal plate is commonly more or less extensively perforated; while the interseptal loculi are crossed by "synapticulæ."

3. *Perforata.*—The calcareous tissue of the corallum is more or less porous (fig. 101), loosely aggregated, spongy, or reticulate, the walls in all being perforated with more or fewer apertures. The septa are generally well developed, but they are also perforated by apertures, and may be simply trabecular. Imperfect dissepiments may be present, and in some cases there are well-developed tabulæ; but the visceral chamber is usually more or less completely open from top to bottom. The three families comprised in this section are the *Eupsammidæ*, the *Madreporidæ*, and the *Poritidæ*, to which must be added the great and almost extinct family of the *Favositidæ*.

In addition to the above-mentioned groups of the *Zoantharia sclerodermata*, two other groups have been established under the names of the *Tabulata* and *Tubulosa*. The former of these included the so-called "Tabulate Corals," distinguished by the imperfect development of the septa, and the fact that the visceral chamber is divided into compartments by horizontal plates or "tabulæ" (fig. 98, D). Some of the so-called "Tabulate Corals," however, such as *Millepora*, have been shown to be *Hydrozoa;* others, such as *Pocillopora* (fig. 98) belong to the Aporose division of the *Zoantharia sclerodermata;* others, again, such as *Favosites*

and its allies, belong to the Perforate division of the *Z. sclerodermata*, and are very nearly related to the *Poritidæ;* others are referable to the *Alcyonaria;* while others, lastly, are of uncertain affinities. It is clear,

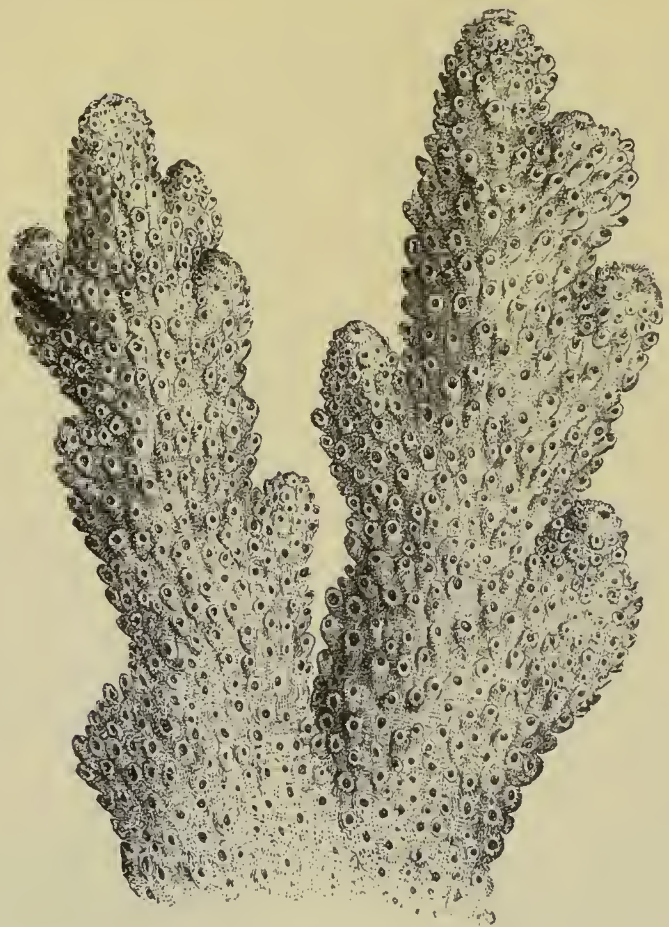

Fig. 101.—*Madrepora plantaginea*, a Perforate Coral, of the natura size, showing the porous texture of the skeleton.

therefore, that the section *Tabulata* can no longer be retained as a division of the *Zoantharia sclerodermata*, or as a division of the Corals of any zoological value. The section *Tubulosa* (including only the Palæozoic genera *Aulopora* and *Cladochonus* or *Pyrgia*) is also of no zoological value, in the present state of our knowledge. The forms included in it are simple or compound, with trumpet-shaped thecæ, rudimentary septa, and few or imperfect tabulæ; and they are probably referable to the *Alcyonaria.*

As regards their distribution in space, the *Zoantharia sclerodermata* are partly inhabitants of deep water, and partly shallow water forms. Many of the latter are capable of growing to very large dimensions, and under favourable circumstances

they give rise to vast aggregations of coral, which assume a geographical importance, and are known as "coral-reefs." The so-called "reef-building" corals have their distribution conditioned by the mean winter temperature of the sea, a temperature of not less than 66° being necessary for their existence. The seas, therefore, which possess the necessary temperature, may be said to be all comprised within a distance of about 1800 miles of the equator on each side. Within these limits, however, apparently owing to the influence of arctic currents, no coral-reefs are found on the western coasts of America and Africa. They are found chiefly on the east coast of Africa, the shores of Madagascar, the Red Sea, and Persian Gulf, throughout the Indian Ocean and the whole of Polynesia, and around the West Indian Islands and the coast of Florida. The headquarters of the reef-building corals may be said to be round the islands and continents of the Pacific Ocean. A "coral-reef" is a mass of coral sometimes many hundred miles in length, and it may be many hundreds of feet in thickness, produced by the combined growth of different species of coralligenous *Actinozoa*. As before said, a mean winter temperature of not less than 66° is necessary for their existence, and therefore nothing worthy of the name of a "coral-reef" is to be found in seas so far removed from the equator as to possess a lower winter temperature than the above.

According to Darwin, coral-reefs may be divided into three principal forms—viz., Fringing-reefs, Barrier-reefs, and Atolls, distinguished by the following characters:—

1. *Fringing-reefs* (fig. 102, 1). These are reefs, seldom of great size, which may either surround islands, or skirt the shores of continents. These shore-reefs have no channel of any great depth intervening between them and the land, and the soundings on their seaward margin indicate that they repose upon a gently sloping surface.

2. *Barrier-reefs* (fig. 102, 2).—These, like the preceding, may either encircle islands, or may skirt continents. They are distinguished from fringing-reefs by the fact that they occur usually at a much greater distance from land, that there intervenes a channel of deep water between them and the shore, and that soundings taken close to their seaward margin indicate considerable depths. If the barrier-reef surround an island, it is sometimes called an "encircling barrier-reef," and it constitutes with its island what is called a "lagoon island."

As an example of this class of reefs may be taken the great barrier-reef on the N.E. coast of Australia, the structure of which is on a perfectly colossal scale. This reef runs, with a few breaches in its continuity, for a distance of more than a thousand miles, its average distance from the shore being between twenty and thirty miles, and the depth of the inner channel being from ten to sixty fathoms, whilst the sea outside is "profoundly deep" (in some places over 1800 feet).

3. *Atolls* (102, 3).—These are oval or nearly circular reefs of coral,

enclosing a central expanse of water or lagoon. They seldom form complete rings, the reef being usually breached by one or more openings, which are always situated on the leeward side, or on that side which is most

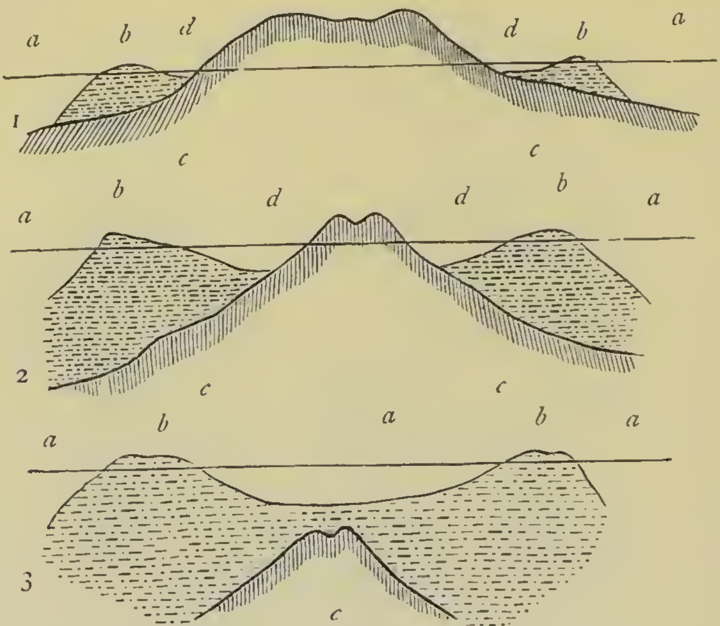

Fig. 102.—Structure of Coral-reefs. 1. Fringing-reef; 2. Barrier-reef; 3. Atoll. *a* Sea-level; *b* Coral-reef; *c* Primitive land; *d* Portion of sea within the reef, forming a channel or lagoon.

completely sheltered from the prevailing winds. In their structure they are identical with "encircling barrier-reefs," and differ from these only in the fact that the lagoon which they enclose does not contain an island in its centre.

If a coral-reef be observed—say a portion of an encircling barrier-reef—the following are the general phenomena which may be noticed. The general shape of the reef is triangular, presenting a steep and abrupt wall on the seaward side, and having a long and gentle slope towards the land. The outer margin of the reef is exposed to the beating of a tremendous surf, whilst the soundings taken just outside the line of breakers always indicate great depths. The longer inner slope is washed by the calm waters of the inner lagoon or channel. The reef is only very partially composed of living corals, which are found to occupy a mere strip, or zone, along the seaward margin of the reef; whilst all above this, as well as all below, is constituted by dead coral, or "coral-rock."

As to the method in which such a reef is produced, the following facts have been established:—

A. The coral-producing polypes do not flourish at levels higher than extreme low water, though some of them can withstand exposure to the sun and air without injury. It follows from this that no coral-reef can be raised above the level of the sea by the efforts of its builders. The agency whereby reefs are raised above the surface of the sea is the denuding power of the breakers which constantly fall upon their outer margins. These detach large masses of dead coral and heap them up in particular places, until an island is gradually produced. The fragments thus accumulated are

compacted together by the finer *detritus* of the reef, and are cemented together by the percolation of water holding carbonate of lime in solution. In this way the upper surface of the reef, along a line of greater or less breadth, is more or less completely raised above the level of high water. It is obvious, however, that the reef might be entirely destroyed by a continuation of this process—the sea being quite competent to undo what it had done—unless some counteracting force were brought into play. This counteracting force is found in the vital activity of the living corals, which form the seaward margin of the reef, and which, by their growth, prevent the sea from *always* destroying the masses of sediment which it may have thrown up.

B. The coral-producing polypes are essentially shallow-water animals, and cannot exist at depths exceeding some 15 to 30 fathoms. It follows from this that no coral-reef can be commenced upon a sea-bottom deeper than about 30 fathoms. The question now arises—In what way have reefs been produced, which, as we have seen, rise out of depths of 300 fathoms or more? In answer to this question, Darwin brought forward the theory that the production of barrier-reefs and atolls was really to be ascribed to a gradual subsidence of the foundations upon which they rest. Thus, if a fringing-reef which surrounds an island be supposed gradually to sink beneath the sea, the upward growth of the corals will neutralise the downward movement of the land, so far, at any rate, that the reef will appear to be stationary, whilst it is really growing upwards. The island, however, as subsidence goes on, will gradually diminish in size, and a channel will be formed between it and the reef. If the depression should be still continued, the island will be reduced to a mere peak in the centre of a lagoon: and the reef, from a "fringing-reef," will have become converted into an "encircling barrier-reef." As the growth of the reef is chiefly vertical, the continued depression will of course have produced deep water all round the reef. If the subsidence be continued still further, the central peak will disappear altogether, and the reef will become a more or less complete ring surrounding a central expanse of water ; thus becoming converted into an "atoll." The production, therefore, of encircling barrier-reefs and atolls is due, on this theory, to a process of subsidence of the sea-bottom. The existence, however, of fringing-reefs is only possible when the land is either slowly rising, or is stationary.

Recent researches by various observers (Semper, Murray, Guppy, &c.), have shown that Darwin's theory cannot be accepted as a universal explanation of the mode of origin of atolls and barrier-reefs, even if it be partially true. It would, however, be out of place here to enter at length into the causes to which modern investigators refer the different forms of coral-reefs.

As regards their *distribution in time*, the *Zoantharia sclerodermata* are abundant as fossils, and have played an important part in the formation of limestones in the later periods of the earth's history. The earliest examples of the group appear in the Ordovician rocks ; and the great family of the *Favositidæ* is represented by numerous types in the Palæozoic deposits, and especially in the Silurian and Devonian formations. The *Perforata* attained, however, a much greater development in Mesozoic and Cainozoic time, and they appear to have reached their maximum at the present day. The same is true of the

Aporosa, unless, as is not impossible, it should ultimately be found that the so-called "Rugose corals" are truly referable to this section of the *Zoantharia*.

CHAPTER XIII.

RUGOSA.

THE members of this order agree with the *Zoantharia sclerodermata* in possessing *a well-developed sclerodermic corallum, with a true theca, but generally possessing both tabulæ and septa combined. The septa, however, are generally, though not always, arranged tetramerously ; and there is commonly a single predominant septum (sometimes three such), or a vacant space (fossula) representing such a septum.* Some of the *Rugosa* are simple, others are compound; but the latter are destitute of a true cœnenchyma. The mode of increase in the compound forms is principally by calicular gemmation, or by lateral budding.

The organisms which have usually been included under the name of *Rugosa* are probably of different affinities ; and as they are extinct, and therefore only known to us by their hard parts, there are many points in their structure which are only imperfectly understood. The *typical* members of the *Rugosa* are clearly Actinozoan, and are, in fact, obviously nearly related to the *Zoantharia sclerodermata*. In both of these groups the corallum may be simple or compound; in both alike the simple form of corallum (fig. 104) consists of an outer wall or "theca," enclosing a central space or "visceral chamber," which is divided into compartments by a series of radiating lamellæ or "septa"; in both alike the structures known as "dissepiments," "tabulæ," and "columella," may be developed; and in both alike the compound corallum may be regarded as a variously-formed aggregate of

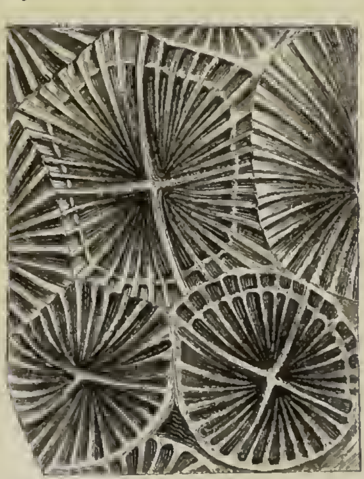

Fig. 103.—A few calices of *Stauria astræiformis*, enlarged, showing the four primary septa forming a four-branched cross. Silurian. (After Milne-Edwards and Haime.)

"corallites," similar in their fundamental structure to the simple corallum.

On the other hand, the corallum of the *Rugosa* exhibits the following more striking peculiarities: (1.) The septa appear to be primitively developed in *four* systems, instead of six. Sometimes the adult corallum (as in *Stauria*, fig. 103) exhibits the four primitive septa in a pre-eminently developed condition, but this is not commonly the case. Very often, indeed, the tetrameral arrangement of the septa is very obscure, or cannot be made out at all. (2.) The septa may be rendered more or less irregular in their arrangement by the presence of a curious vacant space (sometimes three or four), which is known as the "fossula" (figs. 97, B, and 104, B), and which

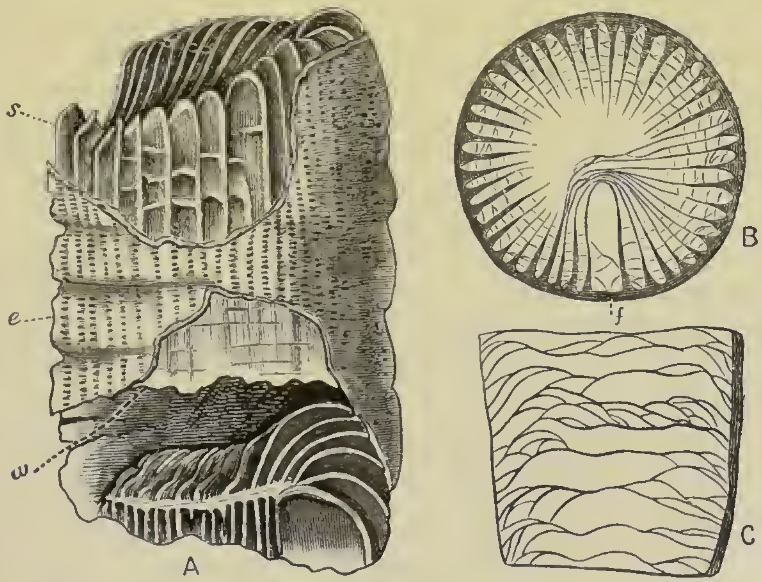

Fig. 104.—Morphology of the *Rugosa*. A, Fragment of *Zaphrentis gigantea*, showing the septa (*s*) with the sparse dissepiments crossing the interseptal loculi, the epitheca (*e*), and the thin proper wall (*w*). B, Transverse section of *Zaphrentis Guerangeri*, showing the septa and dissepiments, the central area occupied solely by the tabulæ, and the "fossula" (*f*). C, Longitudinal section of the last, showing the arrangement of the tabulæ. (A is after Edwards and Haime; B and C are after James Thomson.)

appears to take the place of one of the primitive four septa. (3.) When the septa are well developed, they generally present themselves in the adult as of two sizes only, a larger and a smaller (fig. 97, B). (4.) *Tabulæ* are usually present, in conjunction with the septa. (5.) The compound coralla possess no true cœnenchyma, and one of their commonest modes of increase is by means of "calicular gemmation."

As regards one of the above-mentioned peculiarities—viz., the tetrameral arrangement of the septa—not only is it impos-

sible to demonstrate this in all the forms of the *Rugosa*, but there are certain recent corals (such as *Guynia* and *Haplophyllia*) which show the same feature, though they are usually regarded as referable to the *Zoantharia sclerodermata*. The curious structure, termed the "fossula," is not universally present in the *Rugosa*, and its significance is not precisely understood. The presence of only two sizes of septa is a phenomenon which can be recognised in some typical forms of the *Zoantharia sclerodermata*. Lastly, "tabulæ" are by no means exceedingly rare among the *Zoantharia sclerodermata*.

From a consideration of these and other similar facts some authorities have been led to regard the entire group of the *Rugosa* as referable to the *Zoantharia sclerodermata*, or even as merely forming a portion of the *Aporosa*. This view is taken by Mr Quelch, and is supported by his investigation of the remarkable recent coral termed *Moseleya latistellata*. In this remarkable form the corallum is composite, and increases by calicular gemmation, and tabulæ are developed in the centre of the visceral chamber, while it has other characters by which it approaches to the *Rugose* family of the *Cyathophyllidæ*.

On the other hand, it has to be borne in mind that the mode of development and the arrangement of the septa in the leading types of Rugose Corals have not hitherto (save in few instances) been investigated with the accuracy necessary for the institution of a reliable comparison between the so-called *Rugosa* and the normal *Zoantharia sclerodermata*. In the meantime, therefore, it seems provisionally best to retain the *Rugosa* as a separate division of corals. That some of the types now usually placed among the *Rugosa* will have to be placed elsewhere, may be taken as certain. It is also certain that the discovery of a type like *Moseleya* has much diminished the gap between the *Rugosa* and the ordinary *Madreporaria*. The affinities of *Moseleya*, however, are with the *Cyathophyllidæ*, whereas there are other well-marked sections of the *Rugosa*, such as the *Zaphrentidæ* and *Cystiphyllidæ*, for the recent relatives of which we have yet to seek.

Fig. 105.—*Calceola sandalina*. An operculate Rugose Coral. Devonian.

Among the more abnormal types which have usually been regarded as referable to the *Rugosa*, are certain singular cup-shaped or conical organisms, in which the mouth of the cup is provided with a lid or operculum. The most remarkable of these is the genus *Calceola* (fig. 105), formerly referred to the *Brachiopoda*, and very abundant in certain parts of the

Devonian system, in which the operculum consisted of a single valve or piece. In *Goniophyllum* four valves were present, and in *Cystiphyllum prismaticum* there were four or more valves in the operculum. It is worthy of notice that some recent corals (species of *Primnoa*, *Paramuricea*, and others) exhibit also a more or less complete operculum. The calices of *Cryptohelia pudica* (one of the Hydroid group of the *Stylasteridæ*) are also protected by a calcareous lamina in front of each.

As regards their *distribution in time*, most of the corals which have usually been referred to the *Rugosa* are essentially Palæozoic, and abound in the Ordovician, Silurian, Devonian, and Carboniferous periods, a few forms also occurring in the Permian rocks. The genus *Holocystis* is, however, a Cretaceous type (Lower Greensand); while the Tertiary genius *Conosmilia* has been referred to the Rugose family of the *Stauridæ*.

CHAPTER XIV.

ALCYONARIA.

THE second great division of the living *Actinozoa* is that of the *Alcyonaria* or *Octactiniæ*, defined by the possession of *polypes with eight pinnately-fringed tentacles, the mesenteries and intermesenteric chambers being also eight in number. The corallum is usually sclerobasic, or spicular, or formed of both an axial sclerobasis and detached spicules; if "thecæ" are present, as is rarely the case, septa are wanting or rudimentary.*

The *Alcyonaria* are essentially distinguished from the *Zoantharia* by the possession of eight unpaired mesenteries and eight tentacles (reduced in some rare cases to six or four).

The mesenteries (fig. 106) are symmetrically grouped round the œsophagus, so that there is a dorsal intermesenteric space, and a ventral one, together with three lateral compartments on each side. The "directive" mesenteries of the ventral side (fig. 106, Nos. 1, 1), have the longitudinal retractor muscles attached to their opposed faces; whilst the opposed sides of the dorsal directive mesenteries have the transverse muscles. The mesenteries are not in pairs; and the order in which they appear has not been precisely investigated, the numbering given in the annexed figure not being certainly known to express the order in which these structures are developed.

With the exception of two genera (*Haimeia* and *Hartea*), both of which are possibly founded upon immature forms, the *Alcyonaria* are all composite, the tubular polypes being united by a cœnosarc, and their body-cavities being placed in com-

munication by means of anastomosing canals, which ramify in the cœnosarc, and permit of a free circulation of nutrient fluids. The form of the colony differs greatly in different cases, but none possess the power of independent locomotion, most being rooted to foreign objects, or sunk in the mud. The polypes, in most of the essential points of their organisation, agree with those of the *Zoantharia*, the mouth opening into a tubular gullet, which in turn communicates freely with the body-cavity, and the œsophagus being connected with the body-wall by means of a series of vertical membranous laminæ or "mesenteries." The mesenteries, however, are only eight in number, and are not paired, one of the tentacles corresponding with and opening into each intermesenteric chamber. A corallum may be wanting, and when present its structure varies. In some cases, lastly, it has been shown that the actinosoma normally consists of two kinds of polypes—one sexual, the other sexless and permanently rudimentary. All the *Alcyonaria* are marine. The recent *Alcyonaria* are divided into five families—viz., the *Alcyonidæ*, the *Tubiporidæ*, the *Pennatulidæ*, the *Gorgonidæ*, and the *Helioporidæ*.

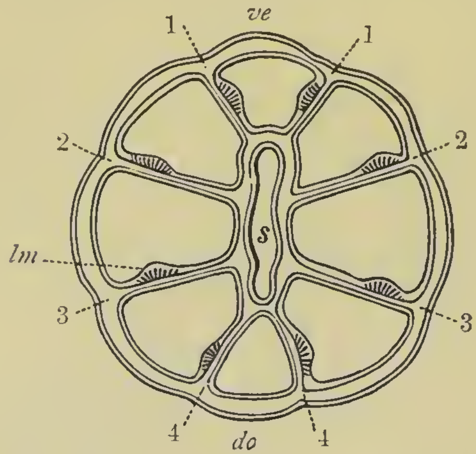

Fig. 106.—Transverse section of a polype of *Alcyonium*, enlarged. (After O. and R. Hertwig.) The numbers indicate the four pairs of mesenteries. *s* Œsophagus transversely divided; *lm* One of the eight longitudinal "retractor" muscles of the mesenteries; *ve* Ventral side of polype; *do* Dorsal side. Nos. 1, 1 and 4, 4 are the "directive" mesenteries.

FAMILY I. ALCYONIDÆ.—This family is characterised by the possession of *a fixed actinosoma, which is provided with a sclerodermic corallum in the form of calcareous spicula embedded in the tissues.* The spicules are mostly fusiform in shape, and are generally present both in the polypes themselves and in the connecting cœnosarc; but there is no central solid axis.

Alcyonium may be taken as the type of the family, and it is well known to fishermen under the name of "Dead-men's fingers." It forms spongy-looking, orange-coloured crusts or lobate masses, which are attached to submarine objects, and are covered with little stellate apertures, through which the delicate polypes can be protruded and retracted at will. The

polypes communicate with one another by an anastomosing system of aquiferous tubes, and the corallum is in the form of cruciform, calcareous spicula scattered through its substance. In the allied *Sarcodictyon* the actinosoma is creeping and linear.

In *Xenia* the colony is branched, and the polypes are non-retractile; and in *Anthelia* and *Sympodium* the actinosoma has the form of a membranous crust attached to foreign bodies. Lastly, in *Sarcophyton* (as shown by Moseley) the colony consists of reproductive zoöids, which have generative organs and tentacles, and of sexless zoöids, which have neither of these organs, but possess a mouth and stomach-sac.

FAMILY II. TUBIPORIDÆ.—In the *Tubiporidæ*, or "Organ-pipe corals," of which *T. musica* (fig. 107) is a familiar example,

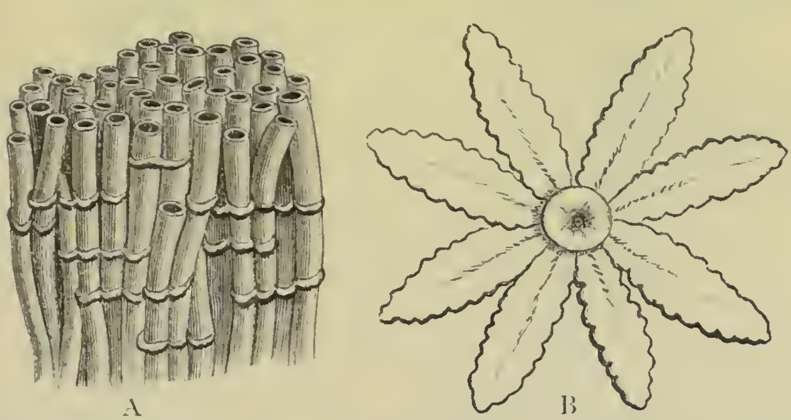

Fig. 107.—A, Portion of the corallum of *Tubipora musica*, of the natural size, showing the tubular corallites and their connecting floors. B, Polype of the same, greatly enlarged, showing the mouth and tentacles.

there is *a well-developed sclerodermic corallum with thecæ, but without septa.* The corallum is composed of a number of bright-red, tubular, cylindrical thecæ, which are united together externally by horizontal plates or floors, which appear to be formed by periodical extensions from the mouths of the tubes. The polypes are usually bright green in colour, and possess eight tentacles each.

As shown by Prof. Perceval Wright, the tubes of *Tubipora* are in reality composed of fused spicules; and the polypes when alarmed retract themselves within their tubes, the upper portions of which are composed of loose fusiform spicules, and are thus capable of withdrawal into the lower dense portion of the thecæ. The Organ-pipe Corals are confined to the warm seas of the "coral-reef region."

FAMILY III. PENNATULIDÆ.—The *Pennatulidæ*, or "Sea-

pens," are defined by their *free* habit, and by the possession of *a sclerobasic rod-like corallum, sometimes associated with sclerodermic spicules.*

Pennatula, or the "Cock's-comb" (fig. 109), consists of a

Fig. 108.—Colony of *Veretillum cynomorium*, of the natural size, with the polypes protruded.

Fig. 109.—*Pennatula sulcata*, seen from the dorsal side. Slightly reduced, after Kölliker.

free cœnosarc, the upper end of which is fringed on both sides with feather-like lateral pinnæ, which bear the polypes; whilst its proximal end is smooth and fleshy, and is probably sunk in the mud of the sea-bottom. This latter portion of the cœnosarc is likewise strengthened by a long, slender, styliform sclerobasis, resembling a rod in shape, whilst spicula occur also in the tentacles and ectoderm.

In *Virgularia* (fig. 110), which, like *Pennatula*, occurs not uncommonly in British seas, the actinosoma is much longer and more slender than in the preceding, and the polype-bearing fringes are short. The sclerobasis is in the form of a long calcareous rod, like a knitting-needle, and part of it is usually naked. In the nearly-allied *Pavonaria* the polype-mass is quadrangular in shape.

In *Veretillum* (fig. 108), the upper portion of the colony is short and club-shaped, and carries the polypes all round its

circumference, and the same is the case in *Cophobelemnon*; whilst in *Renilla* the polypes are unilateral, and the polypiferous cœnosarc is thin and reniform.

In many of the *Pennatulidæ*, as originally shown by Kölliker, the actinosoma consists of two classes of zoöids—the one composed of sexually mature polypes, the other, more numerous, of sexless polypes—which have a body-cavity and stomach, but have neither mouth nor tentacles. These sexless zoöids may be distributed promiscuously over the whole actinosoma (*Veretillum*, &c.), or they may be restricted to definite regions (*Pennatula*, *Virgularia*). Whilst many of the *Pennatulidæ* seem to live habitually sunk partially in the mud of the sea-bottom, others are found freely floating in the water, and their mode of life is not completely understood.

Fig. 110.—Pennatulidæ. *Virgularia mirabilis*. *a* A portion of the stem in the living condition, enlarged; *b* Portion of the stem in its dead condition.

FAMILY IV. GORGONIDÆ. — In the *Gorgonidæ*, or "Sea-shrubs," there is *an arborescent cœnosarc permanently rooted and provided with a grooved, or sulcate, branched sclerobasis, associated with variously-shaped spicules* (fig. 111), *which are secreted by the soft tissues, and are termed "dermosclerites."*

The sclerobasis of the *Gorgonidæ* varies a good deal in its composition. In some it is corneous, and these have often been confounded with the *Antipathidæ*, amongst the *Zoantharia*. The distinction, however, between them is easy, when it is remembered that the polypes in the *Gorgonidæ* have tentacles in multiples of *four*, whilst in the *Antipathidæ* they are in *sixes*. The sclerobasis, too, in the former is always marked by grooves, whereas in the latter it is always either smooth or spinulous. In *Isis* and *Mopsea* the sclerobasis consists of alternate calcareous and horny segments, branches being developed in the former from the calcareous, and in the latter from the horny segments.

In *Corallium rubrum*, the "Red Coral" of commerce (fig. 112), the sclerobasis is unarticulate, or unjointed, and is entirely calcareous. It is an inhabitant of the Mediterranean, and is largely imported for ornamental purposes. Red Coral consists of a branched, densely calcareous sclerobasis, which is finely grooved upon its surface, is of a bright-red colour, and is in reality composed of fused spicules. The corallum is invested by a cœnosarc, also of a red colour, which is studded by the apertures for the polypes, which are white, and possess

eight pinnately-fringed tentacles. The entire cœnosarc is channelled out by a number of anastomosing canals, which communicate with the somatic cavities of the polypes, and are said to be in direct communication with the external medium by means of numerous perforations in their walls. The entire canal system is filled with a nutrient fluid, containing corpuscles, and known as the "milk."

In the typical *Gorgoniæ* the sclerobasis is horny, and more or less arborescent, and the same is the case in the "Fan Corals" (*Rhipidogorgia*, fig. 111, A, B, C), in which the coral-

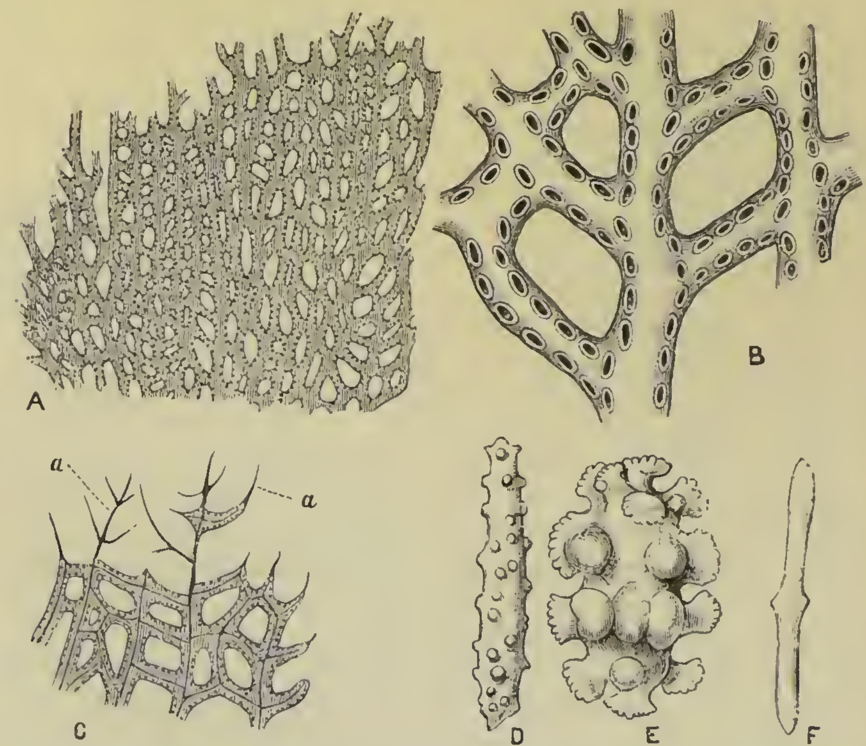

Fig. 111.—A, Fragment of the common Fan-coral (*Rhipidogorgia flabellum*), reduced about one-half. B, Portion of the same enlarged, showing the polype-cells. C, Branchlet of the same partly denuded of the soft parts, and showing the horny axis (*a*). D, E, and F, Flesh-spicules ("dermosclerites") of *Gorgonidæ*, greatly enlarged: D, of *Gorgonia radula;* E, of *Sclerogorgia suberosa;* F, of *Melithæa ochracea.* (After A. Agassiz and Kölliker.)

lum has the form of a regularly reticulate fan-shaped expansion. The soft tissues of the *Gorgonidæ* are abundantly supplied with sclerodermic secretions in the form of calcareous spicules of very various shapes, and often of very brilliant colours, which are in many instances of such characteristic figures that they can be employed as a ground of generic distinction. These spicules ("sclerites") are very generally buried in the soft

tissues, but they may project beyond the surface of the cœnosarc in such numbers as to render the integument rough and prickly.

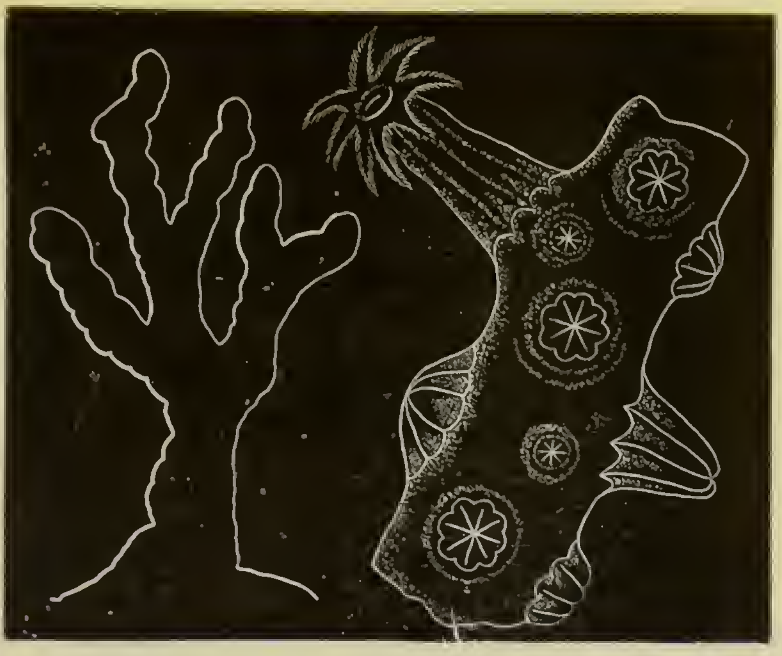

Fig. 112.—Red Coral (*Corallium rubrum*), of the natural size, and a portion enlarged.

Family V. Helioporidæ.—The Alcyonarians of this group possess *a well-developed sclerodermic corallum, composed of tabulate tubes of two sizes, the larger ones being furnished with rudimentary septal laminæ.*

The family *Helioporidæ* has been recently founded by Prof. Moseley for the reception of the living *Heliopora cærulea* (fig. 113), and of a number of extinct corals previously placed in the "Tabulate" section of the *Zoantharia sclerodermata*. In *Heliopora* the corallum is composite and sclerodermic, and composed of corallites united by what has usually been regarded as a "cœnenchyma." The corallites are tubular, crossed by well-developed tabulæ, and having their walls folded in such a manner as to give rise to a variable number (generally twelve) of septal laminæ. The cœnenchyma, so called, is composed of slender tubes, of smaller size than the true corallites, packed closely side by side, crossed, like the corallites, by regular transverse tabulæ, but destitute of septa. The soft parts occupy only the parts of the corallum above the uppermost tabulæ, and therefore only a surface-layer of the colony is actually alive. The polypes are completely retractile, with

eight pinnately-fringed tentacles, and eight mesenteries. The mesenteries, however, have no correspondence with the septa, which are twelve in number as a rule. The septa are thus

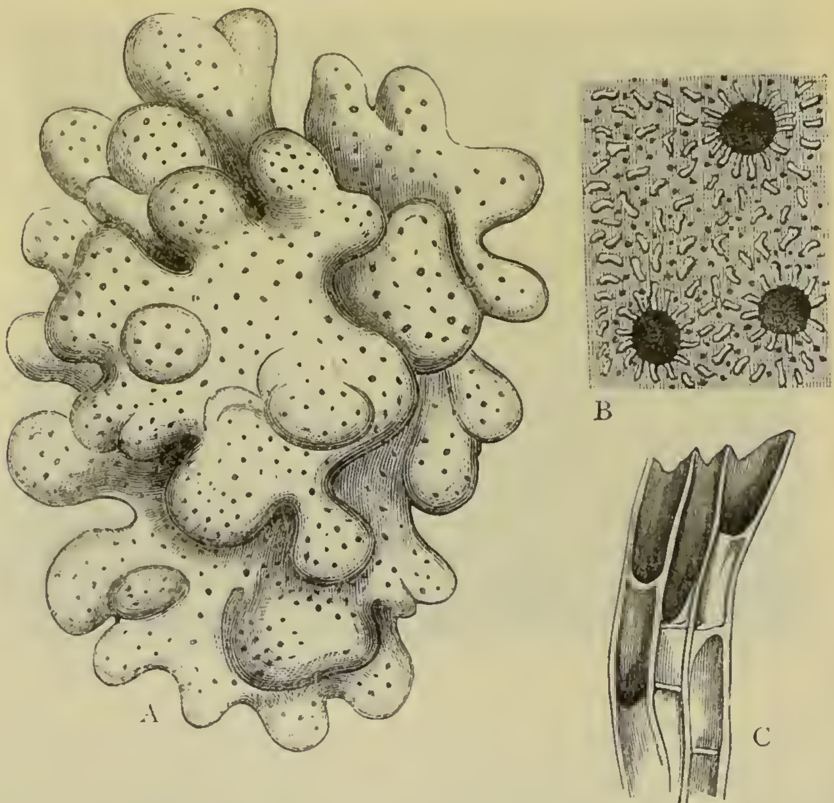

Fig. 113.—A, Colony of *Heliopora cærulea*, of the natural size. B, Portion of the surface of the same, enlarged, showing the apertures of the larger and smaller zoöids. C, Vertical section of a few of the tubes of the same, enlarged, showing the tabulæ. (After Dana.)

seen to be pseudo-septa, and they cannot be regarded as being homologous with the septa of the *Zoantharia sclerodermata*. The so-called cœnenchymal tubes are occupied by sacs lined by the endoderm, which are closed externally, but communicate freely with the body-cavities of the polypes by means of transverse canals; and Prof. Moseley suggests, with great probability, that these are really of the nature of rudimentary sexless polypes. The genus *Heliopora* is confined to the Pacific and Indian Oceans.

Very similar to the recent *Heliopora*, in many obvious characters, are a number of well-known fossil corals, principally Palæozoic, of which *Heliolites* may be taken as the type, and which were formerly regarded as belonging to the "Tabulate" section of the *Zoantharia sclerodermata*. In *Helio-*

lites (fig. 114), there is a well-developed sclerodermic corallum, with comparatively large-sized, tubular, regularly tabulate corallites, usually possessing distinct but rudimentary septa, inter-

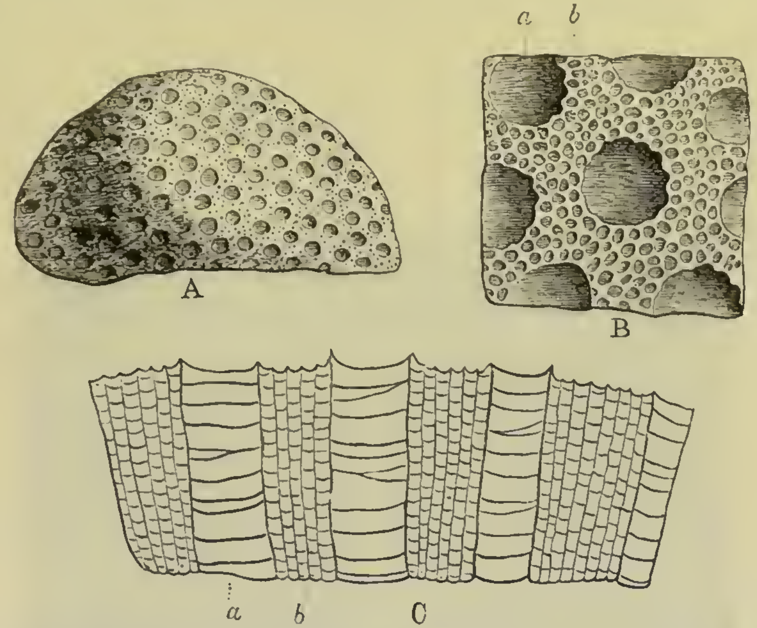

Fig. 114.—A, Small colony of *Heliolites megastoma*, of the natural size. B, Small portion of the surface of the same, magnified, showing the calices (*a*) and the mouths of the cœnenchymal tubes (*b*). C, Vertical section of the same, enlarged, showing the tabulate corallites (*a*), and the tabulate tubes of the cœnenchyma (*b*). (Original.)

mingled with a copious cœnenchyma (so-called) formed of tabulate geometric tubuli, much smaller than the corallites, and destitute of septa. In spite of the close resemblance of *Heliolites* and its allies (*Polytremacis*, *Propora*, *Plasmopora*, &c.) to *Heliopora*, there are certain structural features in the former which will require a thorough investigation before it will be possible to assert with absolute certainty that all these types belong to a single group.

CHAPTER XV.

CTENOPHORA.

Order IV. Ctenophora.—The *Ctenophora* comprise "*transparent, oceanic, gelatinous Actinozoa, swimming by means of 'ctenophores,' or parallel rows of cilia disposed in comb-like plates. No corallum*" (Greene).

The members of this order, sometimes regarded as a separate class, are all free-swimming organisms, and they are placed by many amongst the *Hydrozoa*, from which, however, they appear to be clearly separated by the possession of a differentiated digestive sac, as well as by their analogies with the *Actinozoa*, and their generally superior degree of organisation.

Pleurobrachia (*Cydippe*) may be taken as the type of the order, the structure of all being similar to this in essential points. *Pleurobrachia* (fig. 115) possesses a transparent, col-

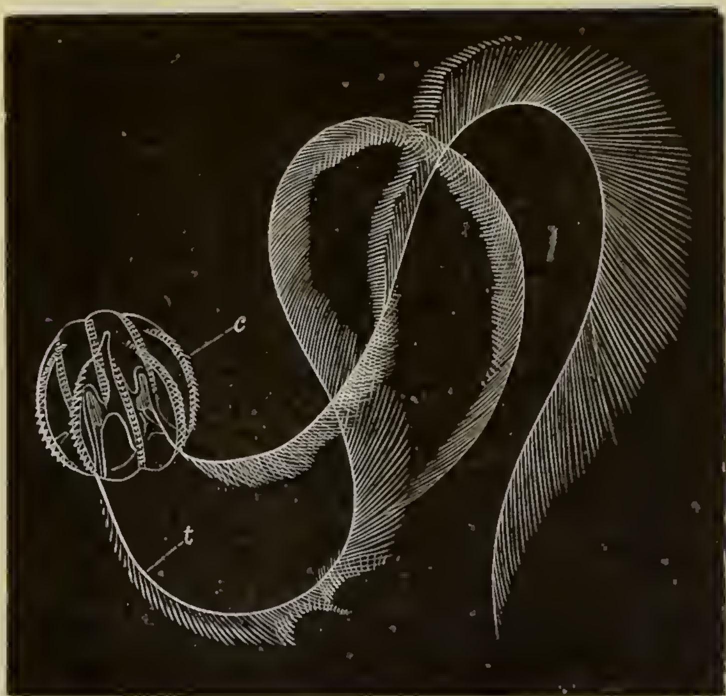

Fig. 115.—Adult of *Pleurobrachia rhododactyla*, in a natural attitude and of the natural size. (After A. Agassiz.) *c* One of the ctenophores; *t* One of the tentacles.

ourless, gelatinous, melon-shaped body, or "actinosoma," in which the two poles of the sphere are termed respectively the "oral" and "apical" (or "aboral"), and the rest of the body constitutes the interpolar region. At the oral pole is the transverse mouth, bounded by lateral, slightly protuberant margins. "Eight meridional bands, or 'ctenophores' bearing the comb-like fringes, or characteristic organs of locomotion, traverse at definite intervals the interpolar region, which they divide into an equal number of lune-like lobes, termed the 'actinomeres'; but this division of the body does not extend into the immediate vicinity of the poles, before reaching which the ctenophores gradually diminish in diameter, each termin-

ating in a point" (Greene). The normal number of the ctenophores is eight (four or twelve in some other forms), and each consists of a band of surface elevated transversely into a number of ridges, to each of which a fringe of cilia is attached, so as to form a comb-like plate. The cilia in the middle of these paddle-like transverse ridges are the longest, and they gradually diminish in length towards the sides, so that the form of each comb is somewhat crescentic. Beside the comb-like groups of vibratile cilia, *Pleurobrachia* is provided with two very long and flexible tentacular processes, which are fringed on one side with small cirrhi. These filamentous processes arise each from a sac, situated on one of the lateral actinomeres, within which they can be completely and instantaneously retracted at the will of the animal.

The mouth of *Pleurobrachia* (fig. 116, *a*) opens into a fusi-

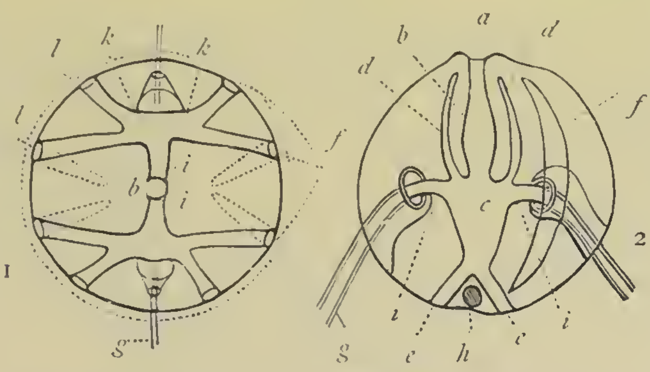

Fig. 116.—Morphology of Ctenophora. 1. Diagrammatic transverse section of *Pleurobrachia*. *b* Digestive cavity; *i i* Primary radial canals; *k k* Secondary radial canals; *l l* Tertiary radial canals; *g* Tentacle.
2. Longitudinal section of *Pleurobrachia*. *a* Mouth; *b* Digestive cavity; *c* Funnel; *d d* Paragastric canals; *e e* Apical canals; *f* Ctenophoral canals; *g* Tentacle; *h* Ctenocyst. (After Huxley.)

form œsophagus (*b*), the lower part of which is provided with brown cells, supposed to discharge the functions of a liver. The gullet opens below into a shorter and wider cavity (*c*), termed the "funnel," from which two canals diverge in the direction of the vertical axis of the organism, to open at the "apical pole." These canals are known as the "apical canals" (*e*), and their apertures as the "apical pores." From the funnel two other pairs of canals are given off. Of these, one pair—known as the "paragastric canals"—turns upwards, one running parallel to the digestive sac on each side (*d*), and "terminating cæcally before quite reaching the oral extremity." The second pair of canals (*i*)—the so-called "radial canals"—branch off from the funnel laterally, each dividing into two,

and then again into two, as they proceed towards the periphery of the body. Thus the two "primary" radial canals produce four "secondary" canals (*k*), and these, in turn, give rise to eight "tertiary" radial canals (*l*), which finally terminate by opening "at right angles into an equal number of longitudinal vessels, the 'ctenophoral' canals (*f*), whose course coincides with that of the eight locomotive bands. These canals end cæcally both at their oral and apical extremities" (Greene). The whole of this complex canal-system is lined by a ciliated endoderm, and a constant circulation of the included nutrient fluid is thus maintained.

Immediately within the apical pole is situated a small cyst or vesicle, supposed to be an organ of sense, and termed the "ctenocyst" (*h*). In structure the "ctenocyst" consists of a spherical vesicle, lined with a ciliated epithelium, and filled with a clear fluid, which contains mineral particles, probably of carbonate of lime. Just beneath the ctenocyst is a cellular mass ("otolith-plate") which is generally believed to be of a nervous nature. The reproductive organs of *Pleurobrachia* are in the form of folds, containing either ova or spermatozoa, and situated beneath the endodermal lining of the ctenophoral canals, one on each side.

The embryo *Pleurobrachia* is at first rudely cylindrical in form, a belt of cilia passing round the middle of its body. This soon breaks up into two lateral groups, which eventually disappear altogether. The primitive ctenophores are four in number, each ultimately breaking up into two.

As regards the homologies between *Actinia* and *Pleurobrachia*, the following may be quoted from Professor Greene :—

"If now a comparison be made between this nutrient system" (the canal-system of the *Ctenophora*) "and that of *Actinia*, the digestive sacs of the two organisms are clearly seen to correspond in form, in relative size, and mode of communication with the somatic cavity. The funnel and apical canals of *Pleurobrachia*, though more distinctly marked out, are the homologues of those parts of the general cavity which in *Actinia* are central in position, and underlie the free end of the digestive sac. So also the paragastric and radial canals may be likened to those lateral portions of the somatic cavity of *Actinia* which are not included between the mesenteries. Lastly, the ctenophoral canals of *Pleurobrachia* and the somatic chambers of *Actinia* appear to be truly homologous, the chief difference between the two forms being, that while in the latter the body-chambers are wide and separated by very thin partitions, they are in *Pleurobrachia* reduced to the condition of tubes ; the mesenteries which intervene becoming very thick and gelatinous, so as to constitute, indeed, the principal bulk of the body." The "apical" canals, again, by which the digestive sac communicates inferiorly with the external medium, may be compared with the perforation which is found in some of the *Actinidæ* (*Cerianthus* and *Peachia*) traversing the axis of the base or foot.

The remaining members of the *Ctenophora* conform in most essential respects with *Pleurobrachia*, the most important differences being found in the canal-system. For purposes of comparison this system may be divided into four portions as follows: 1. The "axial system," consisting of the mouth, stomach, funnel, and apical canals; 2. The "paraxial system," comprising the paragastric canals; 3. The "radial system," comprising the primary, secondary, and tertiary radial canals; 4. The "ctenophoral system," consisting of the tubes which run underneath the locomotive bands.

In *Beroe*, which is in other respects very similar to *Pleurobrachia*, the axial system of canals is the same as we have seen in the latter. The paraxial system, however, consists of *two* pairs of paragastric canals, which, instead of terminating cæcally, open into a circular canal which surrounds the mouth. The ctenophoral canals, likewise, open into the oral vessel, instead of terminating cæcally as in *Pleurobrachia*. Lastly, the radial system is not developed, the ctenophoral canals simply curving round towards their apical extremities, and opening into the funnel directly.

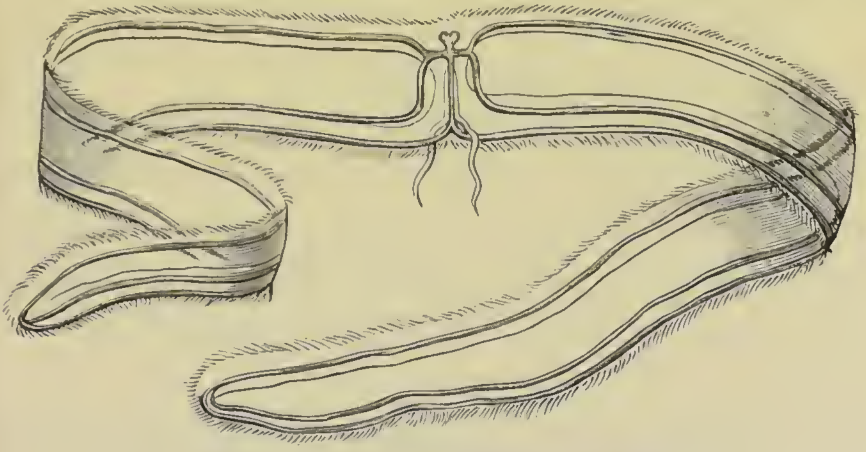

Fig. 117.—Ctenophora. *Cestum Veneris*, reduced in size.

Amongst the *Beroidæ* the mouth extends entirely across the oral extremity of the body; hence they have been termed *Eurystomata*, the term *Stenostomata* being applied collectively to all the other *Ctenophora*.

The *Beroidæ* further differ from *Pleurobrachia* in being destitute of the long tentacular appendages so characteristic of the latter.

In *Cestum*, or "Venus's Girdle" (fig. 117), "elongation takes place to an extraordinary extent at right angles to the direction of the digestive tract, a flat, ribbon-shaped body, a foot or more in length, being the result."

The *Ctenophora* may be divided into the following groups:—

A. EURYSTOMATA.—Oral aperture large, occupying the whole of the oral extremity of the body.

1. *Beroidæ*. The paragastric canals opening into a circumoral ring. No tentacles. Ex. *Beroe*, *Idyia*.

B. STENOSTOMATA.—Mouth small and narrow.

2. *Saccatæ*. No circumoral canal; tentacles two. Ex. *Pleurobrachia*, *Eschscholtzia*, *Hormiphora*.
3. *Lobatæ*. Body furnished with a pair of wing-like oral extensions or lobes. Ex. *Bolina*, *Mnemia*, *Eucharis*, *Lesueuria*.
4. *Tæniatæ*. Body ribbon-like; no oral lobes; two tentacles. Ex. *Cestum*.

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ECHINODERMATA.

CHAPTER XVI.

ECHINODERMATA.

THE *Echinodermata*, including the Sea-urchins, Star-fishes, Sea-cucumbers, &c., form a very distinctly circumscribed group of the animal kingdom, and were formerly included in the old sub-kingdom *Radiata*. The distinctness of the Cœlenterate type from that of the Echinoderms was, however, conclusively demonstrated by Leuckart; and the Cuvierian classification of the two groups in a common "Radiate" sub-kingdom has been almost universally abandoned. On the other hand, there exist undoubted relationships between the Echinoderms and certain of the lower groups of Worms (*Scolecida*); and it was proposed by Professor Huxley, on this ground, to include both groups in a common division of animals for which the name of *Annuloida* was proposed. It appears, however, upon the whole, most in accordance with natural affinities to regard the *Echinodermata* as a distinct primary division or "sub-kingdom," and to consider the Scolecids as a special section of the sub-kingdom *Annulosa*.

The *Echinodermata* may be defined as follows:—

Simple marine organisms, which are mostly bilaterally symmetrical when young, but which in the adult condition have this bilateral symmetry more or less extensively masked by a radial (usually pentamerous) arrangement of their parts. An alimentary canal is present, with or without a distinct anus, separate from the proper body-cavity. A system of water-vessels, often communicating directly with the exterior, and generally connected with protrusible tubes ("feet"), is present. The nervous system is radiate, consisting of an œsophageal ring and radiating branches. The integument is characteristically hardened by the deposition in it of carbonate of lime in the form of plates, granules, or spicules.

The members of this sub-kingdom are known commonly as Sea-urchins, Star-fishes, Brittle-stars, Feather-stars, Sea-lilies, Sea-cucumbers, &c.; and though the fully-grown animal often

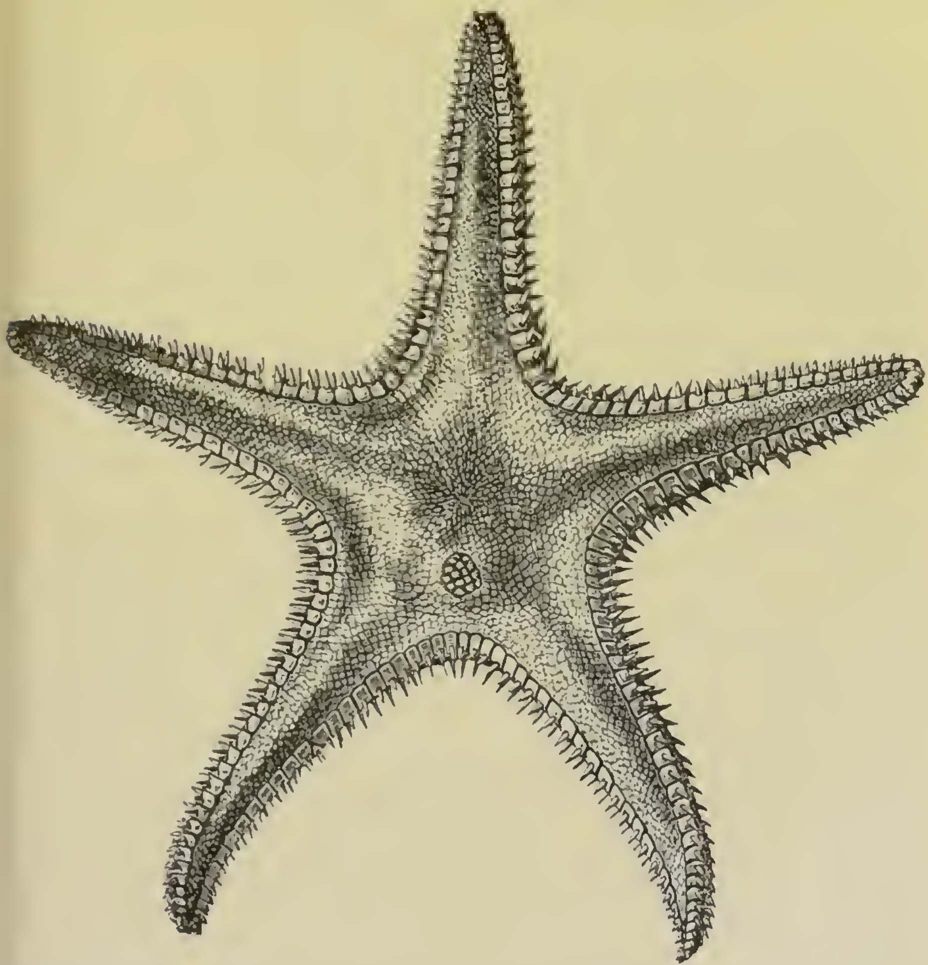

Fig. 118.—Asteroidea. *Archaster bifrons*, viewed from the dorsal aspect. Three-fourths of the natural size. (After Sir Wyville Thomson.)

exhibits distinct traces of bilaterality, this is usually more or less completely masked by the general radiate arrangement of the parts of the body. On the other hand, the embryonic *Echinoderm* usually shows distinct bilateral symmetry. The outer layer of the general integument ("perisome") is ciliated, and the inner layer is more or less hardened by the deposition of carbonate of lime in the form of plates, granules, or spicules. The extent to which this hardening of the integument goes on varies extremely in different groups of the Echinoderms. In some cases, as in the Sea-urchins, the body is enclosed in a continu-

ous series of calcareous plates, which are usually immovably articulated with one another. In the Holothurians, on the other hand, the exoskeleton is usually reduced to mere microscopic spicules or plates developed in the outer layer of the body, only rarely (as in *Psolus*) assuming the form of overlapping scales. Not only does the integument generally become hardened, but lime is also not uncommonly deposited in certain of the internal tissues. Thus portions of the water-vessels commonly have calcareous spicules developed in their walls; while calcareous plates or processes may be produced for the attachment of muscles. The most important of these internal skeletal processes are arched plates (primitively or permanently double), which are developed above the main water-vessels, where they originate from the central circular vessel of the ambulacral system. In all cases, the skeletal structures of the Echinoderms are composed of calcified areolar or connective tissue, the fibres of which enclose oval or rounded meshes (fig. 123, B), thus exhibiting under the microscope an exceedingly characteristic appearance.

The alimentary canal of all Echinoderms is completely cut off from the general body-cavity, and usually communicates with the exterior by both a mouth and an anus; but the latter opening is wanting in the Ophiuroids and in certain Star-fishes. The alimentary tube may be straight or convoluted; and it may give off (as in Star-fishes) lateral diverticula, which have a radial disposition, and some of which may extend into the radiating divisions of which the body is composed.

The general cavity of the body contains a watery "perivisceral fluid," which may represent the blood of higher animals. In this fluid float numerous microscopic bodies, some of which are amœboid masses of protoplasm, resembling the white blood-corpuscles of Vertebrate animals. The lining of the body-cavity being ciliated, a circulation is kept up in the perivisceral fluid, and in this way the process of respiration is partially carried on. There exists, moreover, in the Echinoderms a system of vessels which have usually been regarded as corresponding with the proper blood-vessels of higher animals. This system consists essentially of a circular vessel surrounding the gullet and another similar ring round the termination of the intestine, the two being connected by a vertical bundle of vessels, so united as to look like a single tube, and usually spoken of as the "heart." Branching vessels are distributed to various internal organs, and the entire system has very much the character of the blood-system of a higher animal. There is, however, no certainty as to the precise nature and function of this system;

its vascular nature being entirely denied by some, while it has been compared by others with the pseudohæmal system of the Annelides.

Among the most characteristic of all Echinodermal structures are the so-called "water-vessels" or "ambulacral" vessels. This system consists of a series of musculo-membranous tubes filled with a watery fluid, and connected with the function of respiration, while at the same time commonly subserving locomotion. It consists essentially of a circular vessel which surrounds the commencement of the alimentary canal, and gives off secondary vessels in a radiating manner. The "radiating vessels" usually give off at right angles numerous short lateral tubes (the "tube-feet" or "pedicels"); and the "circular vessel" is generally placed in communication with the exterior by a special canal ("sand-canal"), which opens on the surface by a spongy calcareous plate ("madreporite"). Though commonly subserving locomotion, the ambulacral vessels are probably primarily respiratory in function; and they not uncommonly give off leaf-like or branched external processes ("ambulacral gills"), which serve as respiratory organs. In other cases, the terminal branches of the ambulacral vessels are connected with the sense of touch.

The nervous system of the Echinoderms consists of a pentagonal ring surrounding the gullet, and giving off radiating branches. Though nerve-cells are present, these are not aggregated into definite ganglia. The oral nerve-ring is superficially placed as regards the other circum-œsophageal rings—viz., the vascular and ambulacral rings—and the entire nervous system is closely connected with the epidermal covering of the oral surface of the body.

With one or two exceptions, the sexes are distinct in all Echinoderms; and the testes and ovaries are exceedingly similar to one another. As regards their position, the generative glands alternate with the radiating nerve-cords and ambulacral vessels, and are therefore "inter-radial," while the latter are "radial."

The process of *development* is sometimes direct; but in the typical members of the class a characteristic form of metamorphosis occurs. The impregnated ovum gives exit to an ovoid embryo or "planula," freely locomotive by means of cilia, which are at first diffused over the body, but which soon become restricted to transverse bands, or to definite outgrowths of the body ("epaulets") which are disposed with bilateral symmetry. The larva or "pseudembryo" (fig. 119) next develops an alimentary canal, with a distinct mouth and anus,

dividing the embryonic body into two bilaterally symmetrical halves. A mass of actively formative protoplasm now appears on one side of the stomach, within which are developed a circular and radial tubes, the whole being the rudiment of the ambulacral system of the future *Echinoderm.* A symmetrical calcareous skeleton, not converted into that of the adult, may be developed in the larva (as in the Echinoids and Ophiuroids), or it may be wanting (as in the Asteroids and Holothuroids). The mass of protoplasm, above mentioned as developed on one side of the stomach, rapidly increases in size, envelops the stomach, which it appropriates, and is ultimately converted into the adult Echinoderm; the remainder of the larva being absorbed or cast off as useless.

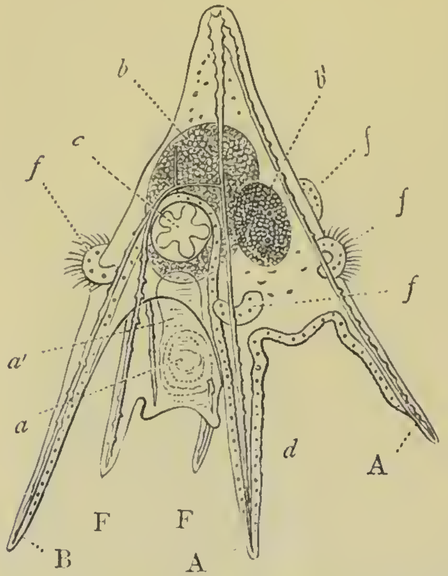

Fig. 119.—Larva of *Echinus* (after J. Müller). A A, Front arms with their internal skeleton; F F, Arms of the mouth-process; B, Posterior side-arm; *a* Mouth; *a'* Œsophagus; *b* Stomach; *b'* Intestine; *d* Ciliated bands; *f f* Ciliated epaulets; *c* Disc of the future *Echinus*.

The essential peculiarity of the development of the typical Echinoderms, as above summarised, is that the larva possesses provisional organs, which may be ultimately absorbed or thrown off, but which are not converted into the corresponding structures of the adult. Thus the larva of an Echinoid (fig. 119) possesses a mouth and alimentary canal, which are not converted into, and in no way correspond with, the mouth and alimentary canal of the adult. The larva or "pseudembryo," as it is termed by Sir Wyville Thomson, leads a perfectly independent existence, and the true Echinoderm is produced from it by a process of internal budding or rearrangement.

Sir Wyville Thomson has, further, shown that there are various cases amongst the *Echinoidea*, *Asteroidea*, *Ophiuroidea*, and *Holothuroidea*, in which the young are developed directly from the egg, without the intervention of a locomotive pseudembryo. In these cases, the eggs are hatched, and the young are brought up, "within or upon the body of the parent, and are retained in a kind of commensal connection with her until they are sufficiently grown to fend for themselves." There

is no sort of organic connection in these cases between the young and the parent; but the young are often brought up in a special receptacle upon the exterior of the mother, to which the appropriate name of the "marsupium" has been given. This viviparous mode of reproduction seems to obtain specially among the Echinoderms of the cold northern and southern seas.

The *Echinodermata* are divided into seven orders—viz., the *Crinoidea*, *Cystoidea*, *Blastoidea*, *Ophiuroidea*, *Asteroidea*, *Echinoidea*, and *Holothuroidea*. Of these, the first is to a considerable extent extinct, and the two next are entirely so; while they exhibit certain structural peculiarities which separate them from the other orders. More particularly, the members of these three orders—viz., the Crinoids, Cystoids, and Blastoids—all possess a dorsally-developed jointed calcareous stalk, which serves to fix them to foreign objects, and which may be only temporarily present. From the presence of this jointed stem, these three orders are grouped together in a single great division, under the name of *Pelmatozoa*. On the other hand, the Echinoids, Asteroids, Ophiuroids, and Holothuroids are devoid of this stalk at all periods of development, and usually creep about by the aid of their tube-feet, with the oral surface of the body turned downwards. They are therefore grouped together in a common division under the name of *Echinozoa*.

CHAPTER XVII.

ECHINOZOA.

ECHINOIDEA.

ORDER ECHINOIDEA.—The members of this order—commonly known as Sea-urchins—are characterised by the possession of a *subglobose, discoidal, or depressed body, encased in a "test" or shell, which is composed of numerous, usually immovably connected, calcareous plates. The intestine is convoluted, and there is a distinct anus. The sexes are distinct, and the larva is pluteiform, and has a calcareous skeleton.* As regards their general anatomy, the "test" of the *Echinoidea* is composed of numerous calcareous plates, which are generally firmly united to one another by their edges, in such a manner that the body of the animal is enclosed in an immovable box. In the singu-

lar Urchins, however, which constitute the family of the *Echinothuridæ*, the plates of the test overlap one another in an imbricating manner, so that the shell becomes quite flexible; and the same is the case with some of the Palæozoic Echinoids. In all living Sea-urchins, and in the great majority of the extinct forms, the test is composed of twenty meridional rows of plates, arranged in ten alternating zones (fig. 120, A), which

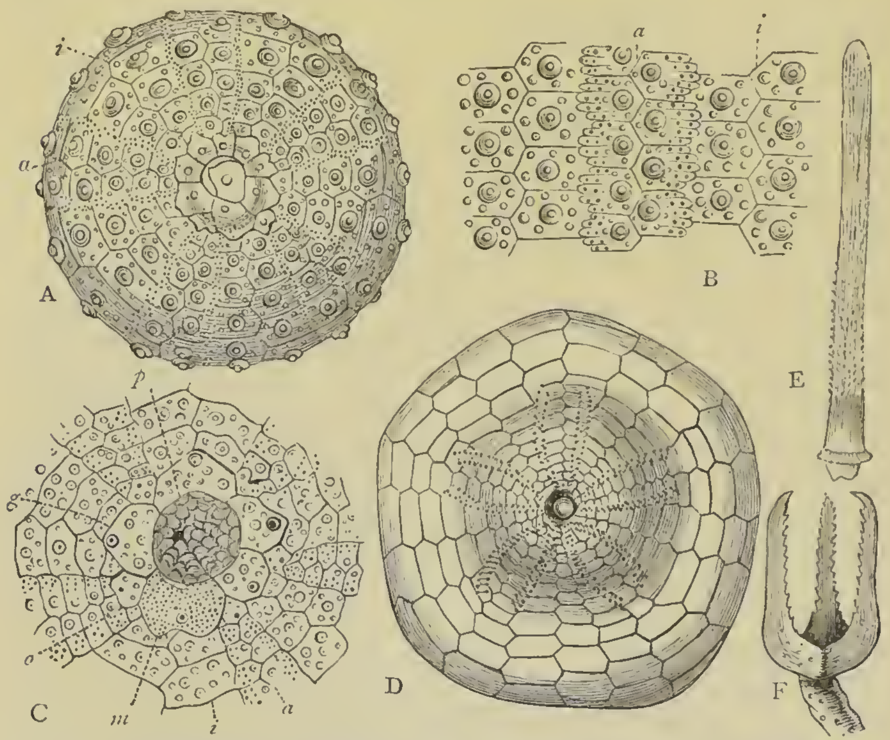

Fig. 120. — Morphology of Echinoidea. A, Young specimen of *Strongylocentrotus Dröbachiensis*, viewed from above. B, Small portion of the test of the same, magnified. C, Summit of the test of *Echinus esculentus*, magnified. D, *Clypeaster subdepressus*, viewed from above, showing the petaloid ambulacra. E, Spine of *Porocidaris purpurata*. F, Pedicellaria of *Toxopneustes lividus*. *a a* Ambulacral areas; *i i* Interambulacral areas; *g* Genital plate; *o* Ocular plate; *m* Madreporiform tubercle; *p* Membrane surrounding the anus. (Figs. A, B, and D are after A. Agassiz.)

typically pass from one pole of the shell to the other, and each of which is composed of two similar rows of plates. Five of these double rows are composed of large plates, which are not perforated by any apertures (fig. 120, A and B, *i*); the zones formed by these imperforate plates being termed the "interambulacral areas." The other five double rows of plates alternate regularly with the former, and are termed the "ambulacral areas," or "poriferous zones." Each of these zones (fig. 120, A and B, *a*) is composed of two rows of small plates, which are perforated by minute apertures for the emis-

sion of the "ambulacral tubes," or "tube-feet." In one great group of the Echinoids, the poriferous zones pass from the centre of the base of the shell to its summit, when they are said to be "perfect" (*ambulacra perfecta*) or "simple." In another great group the poriferous zones are not thus continuous from pole to pole, but simply form a kind of rosette upon the upper surface of the shell. In these cases—as in the common Heart-urchins—the ambulacral zones are said to be "circumscript" (*ambulacra circumscripta*) or "petaloid" (fig. 120, D). Growth of the test is carried on by additions made to the edge of each individual plate, by means of an organised membrane which passes between the sutures where the plates come into contact with one another. The plates of the test are studded with large tubercles, which are more numerous on the interambulacral areas than on the ambulacral (fig. 120, B). These tubercles carry spines (fig. 120, E, and fig. 121), used defensively and in locomotion, which are

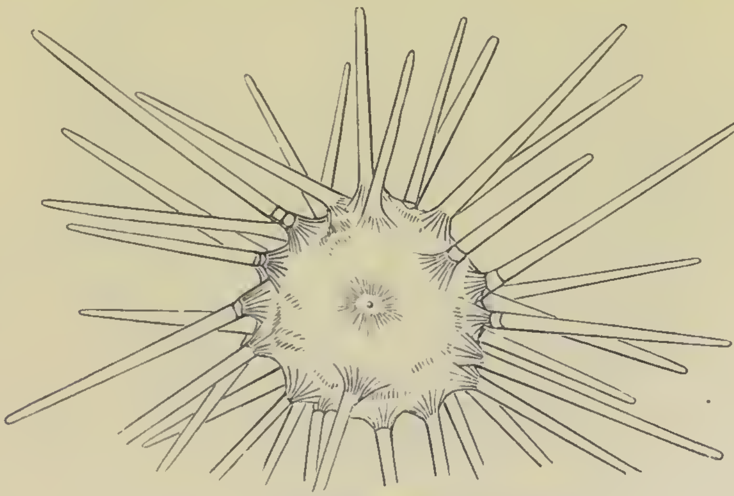

Fig. 121.—*Cidaris papillata*. (After Gosse.)

articulated to their apices by means of a sort of "universal" or "ball-and-socket" joint. Occasionally a small ligamentous band passes between the head of the tubercle and the centre of the concave articular surface of the spine, thus closely resembling the "round ligament" of the hip-joint of man. Besides the main rows of plates just described, forming the so-called "corona," other calcareous pieces go to make up the test of an *Echinus*. The mouth is surrounded by a coriaceous peristomial membrane, which contains a series of small calcareous pieces, known as the "oral plates"; whilst a corresponding series of "anal plates" is found in the membranous

space or "periproct" (fig. 120, C, *p*) surrounding the opposite termination of the alimentary canal. Surrounding the aperture of the anus at the summit of the test is the "apical disc," composed of the so-called genital and ocular plates (fig. 120, C). The "genital plates" are five large plates of a pentagonal form, each of which is perforated by the duct of an ovary or testis. One of the genital plates is larger than the others, and supports a spongy tubercle, perforated by many minute apertures, like the rose of a watering-pot, and termed the "madreporite" or "madreporiform tubercle" (fig. 120, C, *m*). In some cases, this tubercle is not connected with one of the genital plates, but is placed in the centre of the apical disc. The genital plates occupy the summits of the interambulacral areas. Wedged in between the genital plates, and occupying the summits of the ambulacral areas, are five smaller, heart-shaped, or pentagonal plates, known as the "ocular plates," each being perforated by a pore giving exit to an unpaired tentacle, which carries no sucker at its end, and terminates a radiating ambulacral vessel. This "ocular tentacle" is probably an organ of touch, and it has been asserted to be connected with a minute pigmented body at its base, which has been supposed to be an organ of vision; but the existence of this "eye-spot" is denied by high authorities.

Besides the spines, which are sometimes of a very great length, the test bears curious little appendages, called "pedicellariæ" (fig. 120, F), and originally supposed to be parasitic. Each of these consists of a stem, bearing two or three, sometimes four, blades or claws, which snap together and close upon foreign objects like the beak of a bird. Their action appears to be independent of the will of the animal, and their true function is not known; but they may be regarded as peculiarly modified spines. One function performed by the pedicellariæ, in some species at any rate, is the removal of excrementitious particles of food. Such particles, on being ejected from the vent, are seized by the pedicellariæ, passed on from one to another, and ultimately entirely got rid of.

In almost all recent Urchins, the test also carries, as shown by Lovén, curious stalked appendages, with button-like heads covered with cilia. These so-called "sphæridia" are supposed to be organs of sense—probably of taste.

The internal skeleton of the Echinoids is represented by the so-called "auriculæ." These are calcareous arches which are ambulacral or "radial" in position, and spring from the inner surface of the lower edge of the test, just where the imperfectly calcified peristomial membrane begins. Each auricle

forms an arch over one of the radiating ambulacral vessels, and they correspond, therefore, with the so-called "ambulacral ossicles" of the Star-fishes.

Though superficially conspicuously "radial" in its symmetry, the test of the Sea-urchins can nevertheless be shown, with more or less clearness, to have also a bilateral symmetry. This can be demonstrated by the position of such an unpaired organ as the "madreporite," and is more conspicuously exhibited in the "Irregular" Sea-urchins than in the "Regular" forms, though recognisable even in the latter. Thus, if the test of a Regular Sea-urchin (fig. 121 *bis*) be viewed from above

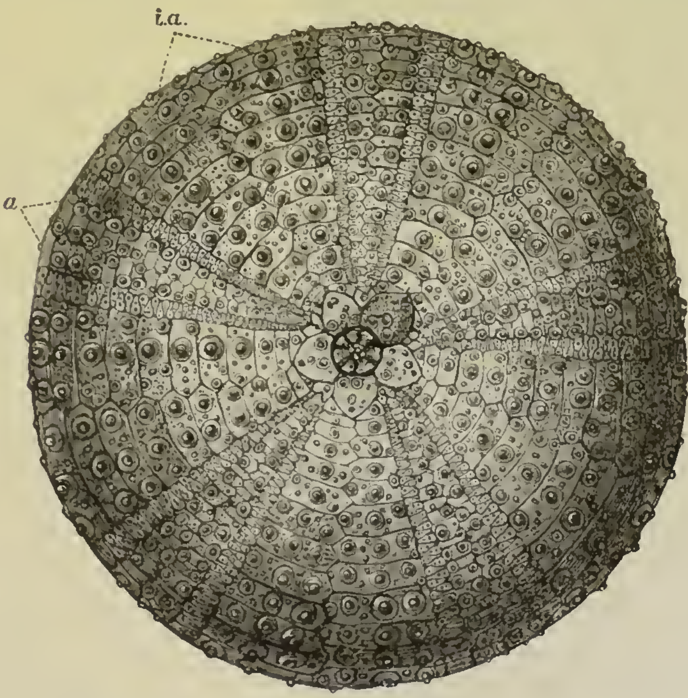

Fig. 121 *bis*.—Echinoidea. Test of *Echinus esculentus*, viewed from above. *a* One of the ambulacral areas; *ia* One of the inter-ambulacral areas.

while held in such a position that the madreporite is placed on the side farthest from the spectator and on his right hand, it will be seen that facing the spectator is an unpaired ambulacral area ("radius"), while on the side nearest him is an unpaired interambulacral area ("inter-radius"). A line drawn through the centre of these two unpaired areas gives a middle line to the body, the structures on either side being for the most part symmetrically disposed. It will further be seen that three ambulacral areas (the "trivium") are directed towards the side farthest from the spectator (the "anterior"

side); while two (the "bivium") are directed "posteriorly," or towards the side facing the spectator. The unpaired ambulacral area is therefore "anterior," and the unpaired interambulacrum is "posterior." In the "Irregular Sea-urchins" the bilaterality is still more marked, the unpaired anterior ambulacrum being usually different to the others in form or size; while the anus is commonly placed on the ventral side of the body, in the unpaired posterior interambulacrum.

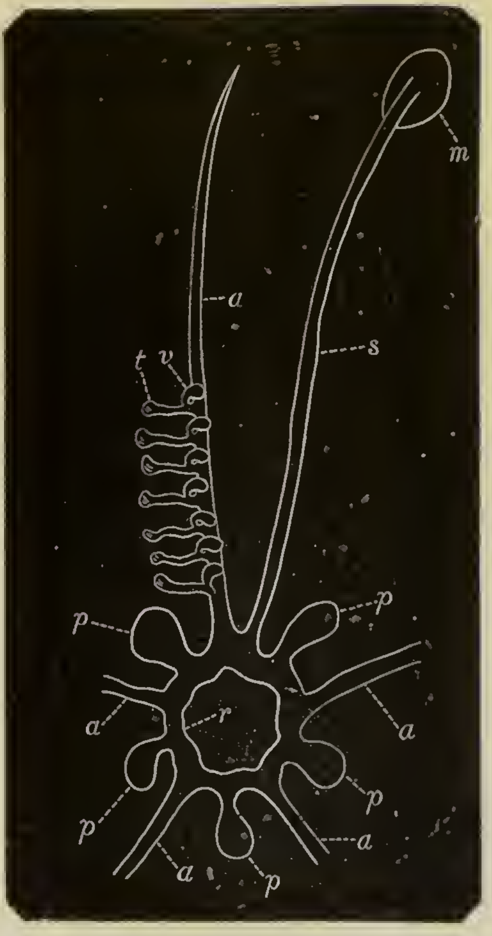

Fig. 122.—Diagram of the ambulacral system of *Echinus*. *m* Madreporiform tubercle; *s* Stone-canal; *r* Central œsophageal ring; *p p* Polian vesicles; *a a* Radiating ambulacral vessels. Only the bases of four of the radiating vessels are shown; and a few of the tube-feet (*t*), with their secondary vesicles or "ampullæ" (*v*), are shown on one side of one of the radiating canals.

Locomotion in the *Echinoidea* is effected in part by means of the spines, but principally by the contractile and retractile "tube-feet" or "pedicels," which are developed in connection with the radiating ambulacral vessels. The general arrangement of the ambulacral system is as follows: From the perforated "madreporite" (fig. 122, *m*) upon the summit of the test there proceeds a membranous canal, the walls of which are hardened by calcareous deposits, and which is known as the "stone-canal" or "sand-canal" (*s*). By this canal water is conveyed to a circular tube (*r*), which surrounds the œsophagus, and constitutes the centre of the ambulacral system. The function of the madreporiform tubercle appears to be that of permitting the ingress of water from the exterior, but of excluding any solid particles which might be injurious; and as its area is much larger than that of the stone-canal, it admits sea-water not only to the ambulacral vessels, but also to the body-cavity. It should

be added, however, that the admission of water to the body-cavity through the madreporic tubercle is denied by Perrier. The "circular canal" (*r*) surrounding the gullet is situated between the nervous and blood-vascular rings, and gives off five branches—the "radiating canals"—which proceed radially along the "ambulacral areas" in the interior of the shell (*a a*). In this course they give off numerous short lateral tubes—the "tube-feet"—which pass through the "ambulacral pores" to gain the exterior of the test, and terminate in suctorial discs. Besides the radiating ambulacral canals, there are connected with the circular canal five special membranous reservoirs (*p p*), known as the "Polian vesicles" (*ampullæ Polianæ*). The ambulacral tubes, or tube-feet, can be protruded at the will of the animal through the pores which perforate the ambulacral areas, and can be again retracted. By means of these locomotion is effected, the tube-feet being capable of protrusion to a length greater than that of the longest spines of the body. The mechanism by which the tube-feet are protruded and retracted is as follows: Each tube-foot, shortly after its origin, gives rise to a secondary lateral branch, which terminates in a vesicle. These vesicles or "ampullæ" (*v*) are provided with circular muscular fibres, by the contraction of which their contained fluid is forced into the tube-feet, which are thus protruded. Retraction of the ambulacral tubes is effected by proper muscular fibres of their own, which expel again the fluid which has been forced into them by the ampullæ. The terminations of the tube-feet contain in many forms a calcareous rosette, often with a calcareous ring below it, whilst the walls of the tube-feet are furnished with calcareous spicules.

The total area over which the tube-feet can be protruded depends upon the extent to which the "ambulacral" or "poriferous" zones of the test are developed. In the typical or "Regular" Sea-urchins, the ambulacral areas are "perfect," and extend from pole to pole; whereas in the so-called "Irregular" Urchins (such as the Heart-urchins and Cake-urchins) the ambulacra are "interrupted," only the upper portions of the ambulacral zones being regularly poriferous. Moreover, in such forms the tube-feet are dissimilar; some, placed on the ventral surface, having suctorial discs, while others are tactile, and others, again, are leaf-like, and are branchial in function.

As regards the digestive system, the mouth is typically situated in the centre of the base; but it may be excentric; and in one singular living form (*Leskia*) it is protected by

valvular calcareous plates. Some forms have the mouth toothless, but others possess a complicated masticating apparatus. In *Echinus* this consists of five long, calcareous, rod-like teeth, which perforate five triangular pyramids, the whole forming a singular structure, known as "Aristotle's Lantern" (fig. 123, C).

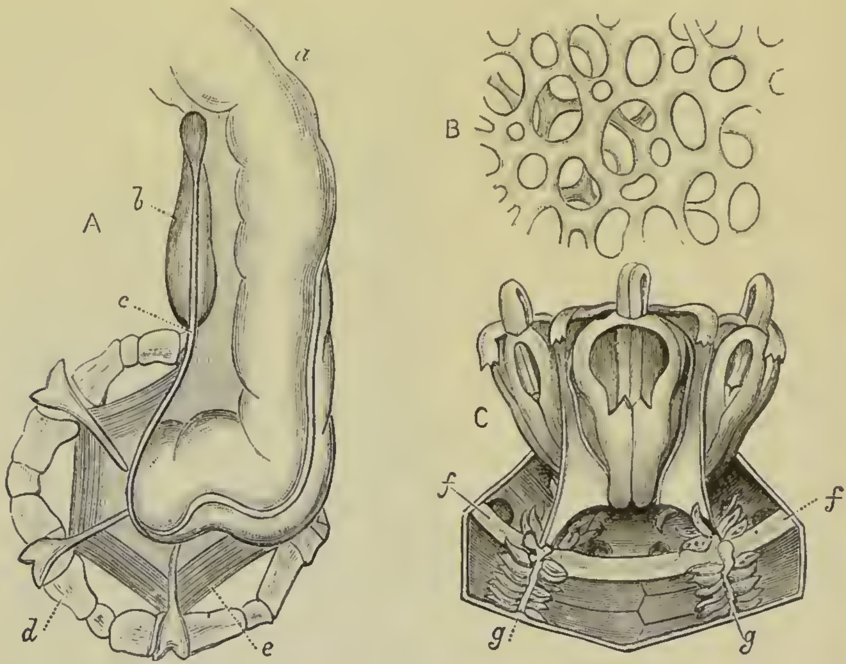

Fig. 123.—A, The masticatory apparatus of an Echinoid (*Toxopneustes lividus*), viewed from above, with part of the alimentary canal attached to it: *a* Œsophagus; *b* Heart, with the sand-canal (*c*) in a groove on one side; *d* The summit of the masticatory apparatus, with some of the muscles (*e*) of the same. B, Minute structure of one of the plates of the test of an Echinus (greatly magnified), showing the calcified areolar tissue. C, The masticatory apparatus of *Echinus esculentus*, viewed from the inside and laterally, as seen in place: *f f* Peristomial margin of the corona; *g g* Two of the radiating ambulacral vessels, with their rows of ampullæ.

The "lantern" is placed in the centre of the space included within the five "auriculæ," and consists of the following parts:—

(1.) Five cutting and pointed calcareous teeth, the wear and tear of which is compensated for by the constant growth of their upper or basal ends. These are placed vertically within—

(2.) Five folded triangular "alveoli," each alveolus enclosing a single tooth. The position of the alveoli is interambulacral.

(3.) Five horizontal pieces, the "rotulæ," which pass from one alveolus to the next, and are opposite the auriculæ, and are therefore ambulacral in position.

(4.) Five spring-like "compass-pieces" or "radii," which pass from the apices of the rotulæ upwards and outwards, and bifurcate at their extremities.

All the above parts are set in motion by a complicated series of striated muscles, by which they are alternately approximated and separated.

The mouth conducts by a pharynx and a tortuous œsophagus to a stomach, opening into a convoluted intestine, which winds round the interior of the shell, and terminates in a distinct anus. The mouth is always situated at the base of the test, and may be central, subcentral, or altogether excentric in position. The anus varies considerably in its position, being usually situated within the apical disc, and surrounded by the genital and ocular plates, when the test is said to be "regular." Sometimes, however, the anal aperture is without the apical disc, and is removed to some distance from the genital plates, when the test is said to be "irregular." In this last case, the anus, instead of being apical, is marginal or submarginal. The convolutions of the alimentary canal are attached to the interior of the test by a delicate mesentery; the surface of which, as well as that of the lining-membrane of the shell, is richly ciliated, and subserves the purposes of respiration.

The so-called vascular system consists of a central fusiform tube (the so-called "heart"), which is enclosed in a common sheath with the sand-canal. This gives off one vessel, which forms a ring round the intestine near the anus, and another which passes downwards, and forms a circle round the gullet, above the "circular canal" of the ambulacral system. Various secondary branches are given off, and the entire system of vessels has been compared with the "pseudohæmal" system of the Annelides, while high authorities have maintained that it is really of a glandular nature.

The nervous system consists of a circular ring, which surrounds the gullet below, or superficial to, the "circular canal" of the ambulacral system, and which sends five branches along the ambulacral spaces, in company with the radiating ambulacral vessels.

The process of respiration is carried on principally by means of the tube-feet and their secondary vesicles, on the one hand, and through the ciliated lining of the test and the mesentery, on the other hand. In most of the Regular Echinoids there are, in addition, five pairs of plumose oral gills, placed in the buccal membrane, where it joins the lower edge of the corona of the test. These organs are ciliated internally, and communicate with the body-cavity. In the Irregular Echinoids these structures are wanting, but the tube-feet which issue from the petaloid ambulacral rosette on the summit of the shell (fig. 120, D) are modified to act as respiratory organs ("ambulacral gills").

The sexes are distinct in all the *Echinoidea*, and the repro-

ductive organs are in the form of five membranous sacs, which occupy the interambulacral areas, and open on the exterior by means of the apertures in the genital plates. In many of the "irregular" Echinoids (such as the "Heart-urchins") there are only four genital glands, and therefore only four genital plates in the apical disc.

As regards their development, most of the Echinoids pass through a metamorphosis, as spoken of previously in treating of the development of the class. In these cases the larva is so unlike the adult animal that it was originally described as a distinct animal under the name of *Pluteus*, from its resemblance to a painter's easel (fig. 119). The larva exhibits bilateral symmetry, and is furnished with provisional organs in the shape of ciliated epaulets, a skeleton of calcareous rods, and an alimentary canal. The adult Echinoid is developed out of a portion of its substance only; and the rest of the larva is absorbed or thrown off. In some Echinoids, on the other hand, as we have seen, the process of development is direct, and there is no "Pluteus" stage, but the young animal is produced viviparously, and simply requires to grow to be converted into the adult.

The typical Sea-urchins are divided into the two great groups of the "Irregular" and "Regular" Echinoids (or the *Echinoidea exocyclica* and *Echinoidea endocyclica*). The Irregular Echinoids have the anus situated outside the genital disc, marginal or submarginal in position, and placed in the unpaired interambulacrum. In some forms, such as the Shield-urchins and Cake-urchins (*Clypeastridæ*), the mouth is placed in the centre of the lower surface, and has a masticatory apparatus, while five genital pores are present. On the other hand, in the Heart-urchins (*Spatangidæ*), the mouth is excentric, without any masticatory apparatus, and only four genital pores are present, the ambulacral rosette being similarly four-leaved. The test in these forms is generally of an oblong, heart-shaped, or ovate figure. The "Regular" Echinoids, on the other hand, have the anus placed at the summit of the test, surrounded by the genital disc; the test is almost always circular or spheroidal; and the mouth is armed with a complicated masticatory apparatus.

Another singular group is that of the *Echinothuridæ*, in which the test is "regular," but the plates of both the ambulacral and interambulacral areas are imbricated and overlap one another, rendering the test quite flexible. The existing genera, *Asthenosoma* (or *Calveria*) and *Phormosoma*, and the Cretaceous genus *Echinothuria* belong to this group.

A fourth group of the Echinoids is that of the *Perischoëchinidæ*, which is not only extinct, but is mostly confined to the Palæozoic period. In all these ancient forms there is the peculiarity that the test consists of *more than twenty rows of plates*, there being a multiplication of either the interambulacral or the ambulacral plates, though there are still only five interambulacral and five ambulacral *areas*. Thus in *Archæocidaris*, *Palæchinus*, *Lepidechinus*, and *Eocidaris*, the ambulacral areas agree with those of the recent Urchins in being composed of only two rows of plates; whilst there are from three to eight or more rows of plates in each interambulacral area. On the other hand, in *Melonites* and *Oligoporus*, the ambulacral areas consist, respectively, of ten and four rows of plates. In some of the *Perischoëchinidæ* the plates of the test are joined by their edges, as in the common living Urchins; but in others (*e. g.*, *Lepidechinus*) the plates overlap in an imbricating manner, as in the recent *Echinothuridæ*, and the test thus becomes flexible.

A fifth group must be constituted for the singular Echinoids which Zittel has termed the *Bothrocidaridæ*. In these the test consists of only fifteen rows of plates, each ambulacral area being reduced to a single row. The only known forms are found in the Ordovician Rocks.

As regards their *distribution in space*, the Echinoids have an extremely wide bathymetrical range, extending from between tide-marks to almost the greatest depths which have yet been explored by the dredge. Various forms (such as the *Toxopneustes lividus* of our own country) have the habit of hollowing out cavities for themselves in the solid rock, in which they spend their existence. Many of the "Irregular" Urchins live buried in sand or mud.

As regards their *distribution in time*, the Echinoids range from the Ordovician period to the present day. Most of the Palæozoic Urchins belong to the family of the *Perischoëchinidæ*, the two principal genera being *Archæocidaris* and *Palæchinus*, of which the latter ranges from the Silurian to the Carboniferous, while the former is solely found in Carboniferous strata. *Melonites* and *Oligoporus* are exclusively Carboniferous; and *Lepidechinus* and *Eocidaris* are principally so, though both commence their existence in the Devonian. The only known Secondary types of the *Perischoëchinidæ* are the Triassic genera *Anaulocidaris* and *Tiarechinus;* and no Tertiary or recent examples of this group are known to exist.

Most of the Secondary and all the Tertiary *Echinoidea* resemble those now living in being composed of not more than

twenty rows of calcareous plates. The Oolitic and Cretaceous rocks are especially rich in forms belonging to this order, many genera being peculiar; but the number of forms is too great to permit of any selection.

It may be mentioned, however, that the singular genus *Echinothuria*, with its flexible test, the predecessor of the living *Asthenosoma* and *Phormosoma*, is found in the Chalk.

CHAPTER XVIII.

ASTEROIDEA AND OPHIUROIDEA.

ORDER ASTEROIDEA (*Stellerida*).—This order comprises the ordinary Star-fishes, and is defined by the following characters:—*The body* (fig. 124) *is star-shaped or pentagonal, and consists*

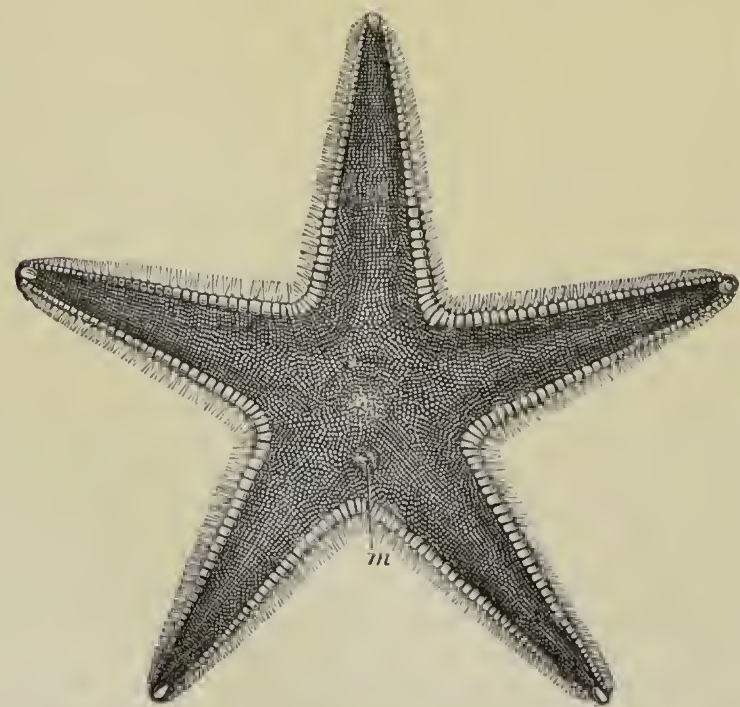

Fig. 124.—*Astropecten irregularis,* viewed from the upper surface; *m* Madreporite.

of a central body or "disc," surrounded by five or more lobes or "arms," or "rays," which radiate from the body, are hollow, and contain prolongations of the viscera. The body is not enclosed

in an immovable box, as in the *Echinoidea*, but *the integument* ("*perisome*") *is coriaceous, and is strengthened by irregular calcareous plates, or studded by calcareous spines. No dental apparatus is present. The mouth is inferior, and central in position: the anus either absent or dorsal. The ambulacral tube-feet are protruded from grooves on the under surface of the rays. The larva is vermiform, and has no pseudembryonic skeleton.*

The general shape of the body varies a good deal in different members of the order. In the common Star-fish (*Asterias*, or *Uraster*, *rubens*) the disc is small, and is furnished with long, finger-like rays, usually five in number. In the *Cribellæ* the general shape of the body is very much the same. In the *Solasters* the disc is large and well marked, and the rays are from twelve to fifteen in number, and are narrow and short (about half the length of the diameter of the body). In the *Goniasters* the body is in the form of a pentagonal disc, flattened on both sides; the true "disc" and rays being only visible on the under surface of the body. In the singular genus *Brisinga*, we have in some respects a transitional form between the Asteroids and Ophiuroids, the arms being much longer and more slender than is the case in the typical Asteroids, at the same time that they are much thicker and softer than is the case amongst the latter. In none of the true Star-fishes, however, are the arms ever sharply separated from the disc, as in the *Ophiuroidea*, but they are always an immediate continuation of it.

The entire upper surface of a Star-fish is covered with a leathery or coriaceous skin, in which carbonate of lime is more or less extensively deposited. For the most part, the skeletal structures have the form of irregular plates or ossicles, often so united as to form a sort of chain-armour. Many of the plates are developed into spines, and some of these (termed "paxillæ") may have the form of a basal stem, with a divided or brush-like end. The plates on the lateral margins of the arms ("marginal plates") are often specially developed, and the ambulacral grooves on the lower surface of the arms are bordered on each side by a row of "adambulacral" plates (fig. 125). "Pedicellariæ" are usually abundantly developed, and generally consist of a short stem carrying a pair of pincer-like blades.

The dorsal surface shows the striated "madreporite" (sometimes more than one), which is placed in the angle between two rays (fig. 124, *m*). When the Star-fish is held in such a position that the madreporite is turned towards the spectator (as in fig. 124), it will be seen that an unpaired ray is directed away from the spectator, and an unpaired interradius towards

him. Three rays ("trivium") are turned forwards, and two rays (*bivium*) backwards; and a line bisecting the madreporite and the unpaired ray gives a middle line to the body. Also upon the upper surface, a little to the left of the middle line, may be found the minute aperture of the anus; but this is wanting in some cases (in the genera *Astropecten*, *Ctenodiscus*, and *Luidia*).

On the lower surface of the body of a Star-fish is seen the centrally-placed mouth, from which radiate a series of deep grooves ("ambulacral grooves"), one of which runs along the under surface of each ray to its extremity. These grooves lodge the radiating ambulacral vessels, with their tube-feet, and the radiating nerve-cords, and they are not covered inferiorly by the integument. On the other hand, as will be subsequently pointed out in greater detail, they are bounded superiorly by an internal skeleton (figs. 125 and 126) composed

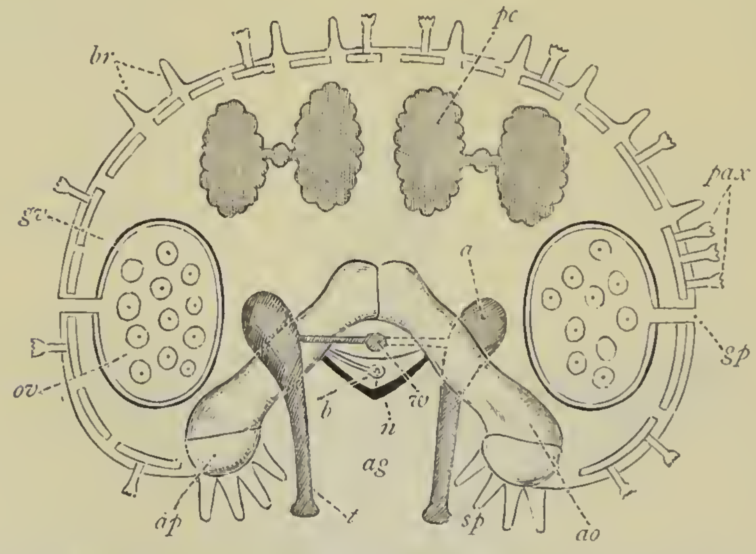

Fig. 125.—Diagram of the cross-section of an arm of *Asterias* (*Uraster*) *rubens*. (After P. Herbert Carpenter.) On the left side the section is supposed to pass between two of the ambulacral ossicles, but on the right side through one of them (*ao*). *ag* Ambulacral groove; *n* Radial nerve; *b* Radial blood-vessel; *w* Radiating ambulacral vessel; *a* One of the ampullæ; *t* One of the tube-feet; *ap* One of the adambulacral plates; *sp* Marginal spines; *pax* Compound spines ("paxillæ"); *ov* Ovary; *gp* Genital pore; *gv* Genital blood-vessel; *br* Respiratory tubes ("dermal branchiæ") of dorsal integument; *pc* Pyloric cæca.

of two longitudinal rows of movable calcareous plates, termed the "ambulacral ossicles" (or "vertebral ossicles"). By means of these ambulacral ossicles, the ambulacral grooves are separated from the cavities of the arms themselves, these containing certain of the internal viscera, and being in reality direct pro-

longations of the body. The only structures which pass from the cavity of the ray to the ambulacral groove are the "ampullæ" (fig. 125, *a*), which lie inside the arm, and become connected with the tube-feet by means of minute pores between successive pairs of ambulacral ossicles.

As regards the internal anatomy of the Star-fishes, the centrally-placed mouth is toothless, and leads into a large distensible and protrusible stomach, which gives off five wide folded lateral pouches, the position of which is interradial. Above these the stomach contracts, and then widens into a pentagonal space which gives origin to five bifurcated radial cæca of great length. These are known as the "pyloric cæca" or "hepatic cæca," and extend into the cavities of the arms (fig. 125, *pc*); each consisting of a basal stem which divides into two long branches, these in turn giving off lateral branches which carry secreting follicles. The pyloric cæca are filled with a brownish fluid, and are supposed to represent the liver. The stomach terminates in a short intestine, which usually ends in a minute dorsally-placed anus. The intestine may give off short inter-radial cæca, the number of which varies in different Star-fishes.

The ambulacral system is essentially the same as in the Echinoids, and is connected with the exterior by means of a dorsally-placed "madreporite," two, three, or more of these being occasionally present. The madreporite admits the water to the short "stone-canal," which opens into the circular vessel surrounding the gullet. The circular canal carries five simple or divided "Polian vesicles," and gives off the radiating ambulacral vessels. These run in the roof of the deep ambulacral grooves, immediately below the chain of ambulacral ossicles (fig. 125, *w*), and their number varies with the number of the arms. Each radiating vessel gives off two or four rows of cylindrical tube-feet or pedicels, the ends of which are sucker-like (fig. 125, *t*), and it is by means of these that the Star-fishes creep about, mouth downwards. Some forms have conical tube-feet which do not terminate in suctorial discs. The tube-feet are protruded by means of "ampullæ," which spring from their bases, and pass through pores between successive pairs of ambulacral ossicles, so as to gain the cavities of the arms (fig. 125, *a*). The ampullæ, therefore, form a double row of membranous sacs which lie *above* the chain of ambulacral ossicles, while the radiating vessel and tube-feet are *below* the same.

It follows from the above that there are no structures in the Star-fishes which correspond with the perforated ambulacral plates of the Echinoids. This is at once evident on examining a section of the arm of a Star-fish,

from which the soft parts have been removed (fig. 126). In such a section the ambulacral ossicles (*a a*) are seen in the centre of the lower surface, united movably along the middle line by their inner extremities. They

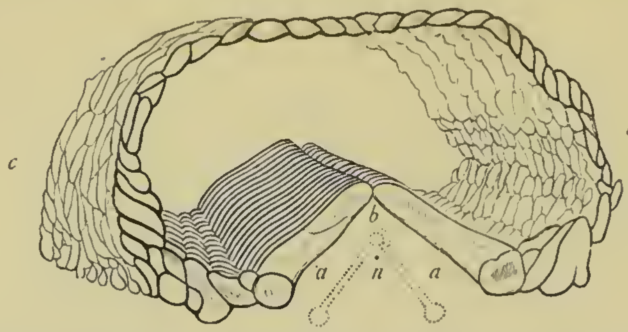

Fig. 126.—Section of the ray of *Asterias* (*Uraster*) *rubens*. *a a* Ambulacral ossicles *b* Position of the ambulacral vessel; *c c* Plates of the external skeleton; *n* Nerve-cord. The dotted lines show the tube-feet proceeding from the ambulacral vessel.

are so placed as to form a kind of elongated pent-house, and immediately beneath the line where the ossicles of one side are united to those of the other side is placed the radiating ambulacral vessel (*b*). Superficial to this, again, is the nerve-cord; so that the whole chain of ambulacral ossicles is placed in the midst of the soft parts of the animal, and it is thus clearly an internal skeleton. The tube-feet, therefore, do not pass through any part of the skeleton on their way to the surface; the integumentary skeleton being, in fact, *absent* along the ambulacral areas. There is thus no representative in the Star-fishes of the "poriferous zones" of the Echinoid test. On the other hand, the ambulacral ossicles of the Star-fishes are represented in the Echinoids by the "auriculæ."

The "vascular" system of the Asteroids consists of an oral and an aboral or anal ring, connected by a central plexus ("heart"), which is enclosed in a common sheath with the stone-canal. Vessels are distributed to the genital glands and stomach, and the oral ring gives off radial branches (fig. 125, *b*), which accompany the radiating ambulacral vessels along the ambulacral grooves.

Specialised respiratory organs cannot be said to exist; but the body-cavity is ciliated, as are the surfaces of the internal organs, and respiration is thus subserved. The lining of the body-cavity is also often protruded through pores in the dorsal integument in the form of delicate ciliated membranous tubes or "dermal branchiæ" (fig. 125, *br*), which doubtless act as breathing-organs.

The nervous system consists of a central pentagonal ring, surrounding the gullet, and sending band-like radiating branches along the ambulacral grooves (fig. 125, *n*). At the extremity of each ray the nerve becomes connected with a pigment-spot or "ocellus," which contains lens-like structures, and

is supposed to be an organ of vision. Each eye-spot may be surrounded by a circle of movable spines or "eyelids." Close to the eye-spot is placed the termination of the radiating ambulacral vessel, in the form of an unpaired terminal tentacle, which carries no sucker, and is probably an organ of touch.

The generative organs are in the form of tubular glands, which resemble bunches of grapes in form, and are arranged in pairs in each ray. They discharge their products by genital pores (fig. 125, *gp*), which usually open in the angles between the arms, generally by minute sieve-like apertures. The generative glands are inter-radial in position, though commonly extending far into the cavities of the arm, below the pyloric cæca.

In their development, the Asteroids occasionally show no metamorphosis, but they usually present the same general phenomena as are characteristic of Echinoderms generally. The larvæ, however, are not provided with a continuous endoskeleton, such as is found in the embryo of the Echinoids and Ophiuroids. In many Asteroids the embryos have continuous ciliated side-lappets, and exhibit complete bilateral symmetry. Such larvæ are known as *Bipinnariæ;* and in these, as in the "Pluteus" of the Echinoids, a large portion of the primitive embryo is ultimately absorbed. In another stage of development, the larval Star-fish is provided with long, slender, movable processes, when it is known as a *Brachiolaria.*

No good *classification* of the Asteroids has as yet been established. In one group (*Asteracanthiidæ*), represented by the common *Asterias* (*Uraster*) *rubens* of British seas, the tube-feet are in four rows in each arm. On the other hand, in the Sun-stars (*Solaster*), and in allied forms, there are only two rows of tube-feet in each arm. In the curious family of the *Astropectinidæ* (comprising the genera *Astropecten*, *Ctenodiscus*, *Luidia*, &c.), there are also two rows of tube-feet in each arm, but these are conical and do not end in suckers, while an anal aperture is wanting in all except *Archaster*. Other groups with two-rowed tube-feet are the *Oreastridæ* and the *Asterinidæ*, the last comprising the well-known Cushion-stars (*Goniaster*) and the Birds'-foot Stars (*Palmipes*). Lastly, a transition is effected between the Asteroids and the Ophiuroids by the singular family of the *Brisingidæ*, in which the arms are long and rounded, sharply marked off from the disc, and having the ambulacral grooves not continued to the mouth.

As regards their *distribution in space*, the Asteroids have a wide range, extending from the littoral zone to great depths in the sea. Upon the whole, however, they are shallow-water forms.

As regards their *distribution in time*, the Asteroids range from the Ordovician to the present day. In the Ordovician and Silurian rocks are many peculiar types (*Palæaster*, *Stenaster*, *Palæodiscus*, *Petraster*, &c.). In the later Palæozoic rocks Star-fishes are not abundant; but many generic types, some of which still survive, are known from the Secondary formations (such as *Plumaster*, *Goniaster*, *Astropecten*, *Oreaster*, *Astrogonium*, *Goniodiscus*, &c.). The Tertiary Star-fishes are few in number, and belong to existing generic types.

OPHIUROIDEA.

ORDER OPHIUROIDEA.—*Body stellate, consisting of a central "disc," in which the viscera are contained, and of elongated "arms," which are sharply separated from the disc, solid, not containing prolongations of the alimentary canal, and not furnished inferiorly with ambulacral grooves. Larva generally pluteiform, with a skeleton.*

This order comprises the small but familiar group of the "Brittle-stars" and "Sand-stars," often grouped along with the *Asteroidea*, to which they are nearly allied. The body in the *Ophiuroidea* (fig. 128) is discoidal, and is covered with granules, spines, or scales, but pedicellariæ are wanting. From the body proceed long slender arms, which may be simple or branched, but which do not contain any prolongations from the stomach, nor have their under surface excavated into ambulacral grooves. The arms, in fact, are not simple prolongations of the body, as in the *Asteroidea*, but are special appendages, superadded for locomotive and prehensile purposes. Each arm (fig. 127) is enclosed by four rows of calcareous plates, one on the dorsal surface, one on the ventral surface, and two lateral. The lateral plates generally carry more or less well-developed spines. In the centre of each arm is an internal skeleton, which occupies the greater part of the space included within the integumentary plates, and which consists of a succession of separate quadrate joints or "ossicles," which are articulated together, and united by muscles. These ossicles represent the "ambulacral ossicles" of the Star-fishes; but each of them is composed of two lateral ossicles immovably united in the middle line, and not movably joined together, as in the Asteroids. Immediately below the chain of ambulacral ossicles runs the radiating ambulacral vessel (fig. 127, *w*), and underneath that again are the radial blood-vessel and nerve-cord (*b* and *n*). The radiating ambulacral vessel gives off the tube-feet, but the ambulacral grooves,

instead of being open as in Star-fishes, are closed in inferiorly by the ventral arm-plates. Hence the tube-feet can only reach the exterior through pores placed between the lateral and ventral plates of the arm. The cross-section of the arm (fig. 127) shows this further important distinction between the Ophiuroids and the Asteroids — viz., that in the former there is no wide extension of the body-cavity lying *above* the chain of ossicles, and containing prolongations of the internal organs, such as occur in the latter.

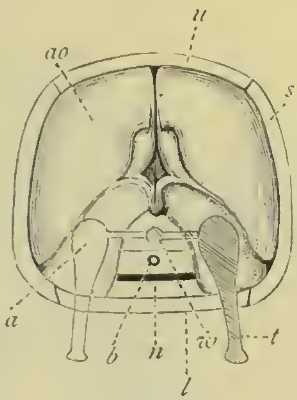

Fig. 127. — Diagram of the cross-section of the arm of an Ophiuroid (slightly altered from Sladen). *ao* Ambulacral ossicle, immovably united with the corresponding ossicle of the opposite side; *u* Superior plate of the arm; *s* Lateral plate; *l* Inferior plate; *n* Radial nerve-cord; *b* Radiating blood-vessel; *w* Radiating ambulacral vessel; *t* Tube-foot; *a* Ampulla.

The mouth in the Ophiuroids is placed in the centre of the lower surface of the body, and is surrounded with a complicated system of plates, some of which have been spoken of as "teeth," though they can hardly have any masticatory function. The mouth opens directly into a wide membranous stomach, but there is no intestine, and therefore necessarily no anus, while the stomach gives off no lateral diverticula.

The vascular system is built upon the same type as in the Asteroids, consisting of an oral and an aboral ring, united by an intervening plexus, which is enclosed in a common sheath with the stone-canal. Radial blood-vessels (fig. 127, *b*) also accompany the radiating nerves and ambulacral tubes. The nervous system has the same form as in the Asteroids.

The ambulacral system is constructed upon essentially the same plan as in the Asteroids and Echinoids, but its place as a locomotive apparatus is taken by the arms. The madreporite is placed on the inferior surface of the body, and is confluent with one of the large inter-radial plates surrounding the mouth. There is a short stone-canal leading into a circular canal, which carries the "Polian vesicles," of which there are usually four. From the circular vessel are given off the radiating ambulacral vessels, which run in the interior of the arms, underneath the chain of ambulacral ossicles (fig. 127, *w*), and give out the tube-feet. These latter are tentacle-like, without terminal suckers, and the ampullæ are only represented by their dilated bases. The tube-feet nearest the mouth are specially modified, and are used in feeding as organs of touch.

The reproductive organs are placed inter-radially, and their ducts open into singular folded pouches, or "bursæ," which in turn communicate with the exterior by means of slit-like openings (the "genital fissures"), which are placed, singly or in pairs, on the sides of the arms inferiorly, at their junction with the disc (fig. 128, C). Not only do these pouches serve

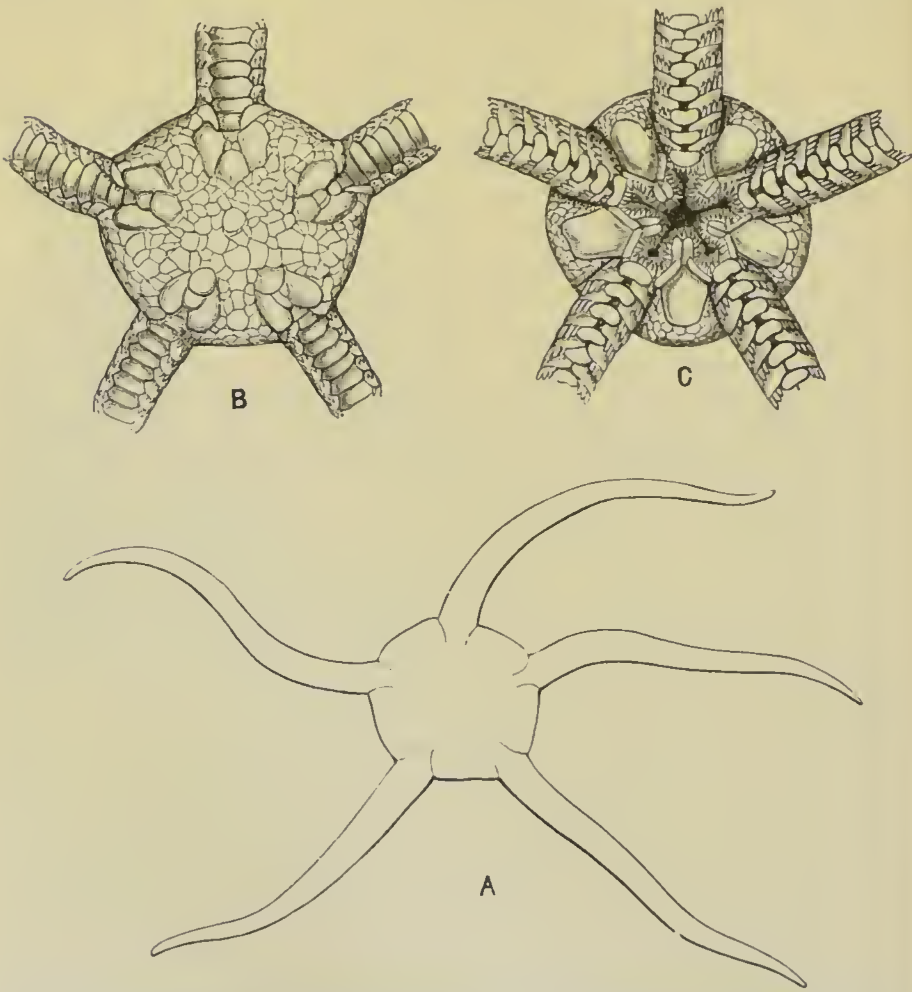

Fig. 128.—Ophiuroidea. *Ophioglypha lacertosa.* A, Outline of the natural size; B, The disc viewed from above, twice the natural size; C, The disc viewed from below, showing the mouth and genital fissures, twice the natural size. (Original.)

for the emission of the generative products, but they also have the sea-water admitted into their interior, and thus serve as respiratory organs.

The development of the Ophiuroids is sometimes direct, the young being brought forth alive, and, in some cases, being carried by the mother for some period after hatching (Wyville

Thomson). More commonly there is a pluteiform embryo, which resembles that of the Echinoids in having a provisional endoskeleton. The embryo (fig. 129) is furnished with long

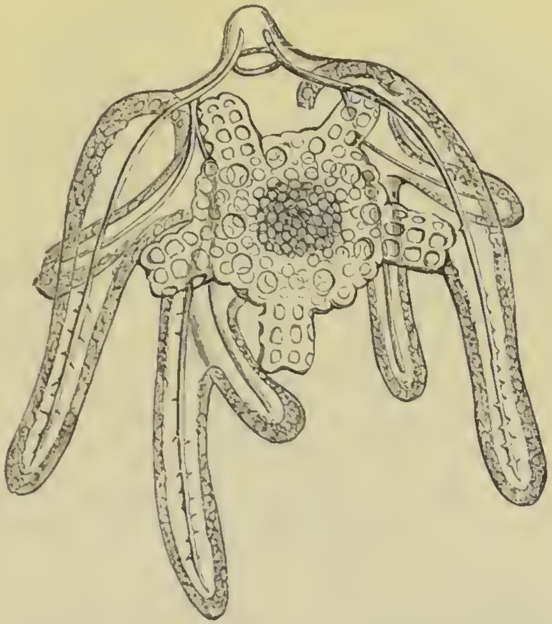

Fig. 129.—*Pluteus paradoxus*, the larva of an Ophiuroid (*Ophioglypha ciliata*) in an advanced state of development (after J. Müller). The larva shows the temporary processes and provisional skeleton of the embryo, together with the stellate body of the adult.

slender locomotive processes or arms, and the adult is formed on one side of the primitive stomach, the larval arms and their contained rods being ultimately wholly absorbed.

There are two principal groups of the Ophiuroids, the typical forms (*Ophiuridæ*) having simple unbranched arms, the under sides of which are covered with dermal plates. In this group are the common Sand-stars (*Ophioglypha*, fig. 128, *Ophiothrix*, &c.). In the group of the *Euryalidæ*, on the other hand, the arms are usually branched, and have their lower surfaces covered with a soft skin, while there are ten genital fissures. A well-known example of this group is the Medusa-head Star (*Asterophyton*), in which the arms are divided from the base, at first dichotomously, and then into many branches.

The Ophiuroids are widely distributed at the present day, being found in all seas, and ranging from between tide-marks to great depths. Fossil forms of the order are known to occur in rocks as old as the Silurian (*e.g.*, *Protaster*).

CHAPTER XIX.

PELMATOZOA.

CRINOIDEA, CYSTOIDEA, AND BLASTOIDEA.

THE three groups of Echinoderms known as the Crinoids, Cystoids, and Blastoids agree with one another in certain common characters, and may be included in a single primary section termed *Pelmatozoa*. In all these forms the body is fixed, either permanently or temporarily, by a jointed stem or peduncle developed from the dorsal surface, the mouth being placed on the opposite side of the body. In its fully developed condition, the peduncle has the form of a jointed stem, containing a neuro-vascular axis in its interior. The body itself is enclosed in a variously modified series of calcareous plates, which represent the apical disc of the Echinoids, and the upper surface may be provided with jointed appendages (the "arms"). The circular ambulacral vessel has no direct communication with the exterior, and the radiating ambulacral vessels (when present) are respiratory in function, and are not subservient to locomotion.

ORDER CRINOIDEA.—The members of this order are Echinoderms, in which *the body is fixed, during the whole or a portion of the existence of the animal, to the sea-bottom by means of a jointed, flexible stalk or peduncle, which springs from the centre of the dorsal or aboral surface. The body is cup-shaped or discoidal, and its dorsal surface is protected by a system of calcareous plates. The mouth is situated on the upper surface, generally in the centre. From the margin of the cup-shaped body spring jointed flexible appendages or "arms," which are primitively five in number, and which carry lateral jointed processes or "pinnules." The upper or ventral surfaces of the arms are furnished with grooves corresponding with the "ambulacral grooves" of the Asteroids. The ambulacral system does not communicate directly with the exterior, and is not connected with locomotion. The reproductive organs are situated beneath the skin in the grooves on the ventral surface of the arms or pinnules. The embryo is primitively free and ciliated, but gives origin to a second larval form, which develops a jointed stalk of attachment.*

As the type of the *Crinoidea*, we may take the common Feather-stars (*Comatula* or *Antedon*). The Feather-stars belong to a group of Crinoids which are known as "Sessile"

Crinoids, because they are not permanently fixed, but are only attached by a stalk when young. Taking the common British species—the *Comatula rosacea* (fig. 130)—as a con-

Fig. 130.—Crinoidea. *Comatula rosacea*, a free Crinoid, viewed from its dorsal or aboral aspect.

venient example, the adult is free, and the pentagonal disc-like body gives origin to five "arms," which bifurcate almost directly so as to give rise to ten long slender processes, which are transversely jointed, and are fringed on both sides by delicate "pinnulæ." The dorsal surface of the body carries a number of delicate jointed flexible processes ("cirri"), by means of which the animal can moor itself to foreign objects, with the mouth turned upwards. It can, however, detach itself at will, and swims readily by an alternate movement of the arms of the right and left sides of the body.

The dorsal integument of *Comatula* is hardened by the formation within it of a system of calcareous plates which form

the so-called "cup" or "calyx," and which are to be regarded as the homologue of the "apical disc" of the Echinoids. The central piece of the calyx ("centrodorsal plate") has soldered on to it five "radial" plates, which represent the "ocular plates" of the Echinoids. Properly speaking, there should intervene between the "centrodorsal" and the "radial" plates a circle of plates corresponding with the "genital plates" of the Echinoids. This intermediate circle of plates is present (as the so-called "basal" plates) in the "stalked" Crinoids, but takes no part in the formation of the exterior of the calyx in the ordinary Feather-stars. The first "radials" are followed by two other circles of radial plates (the "second radials" and axillary "radials"), the outermost circle carrying the bases of the jointed arms.

The upper or ventral surface of the body is covered with an imperfectly calcified coriaceous skin, and carries the aperture of the mouth. In *Comatula rosacea* the mouth is central, as it is in all the ordinary Crinoids; but in some Feather-stars (*Actinometra*) it is quite excentric. The anus is usually supported on a tubular projection, and is excentric in position. The arms of *Comatula rosacea* exhibit on their ventral surface a deep "brachial groove," the elevated margins of which are cut out into minute crescentic respiratory leaves, at the base of each of which is a group of three tentacles, connected with a cavity in the interior of the respiratory leaf, and communicating by a common trunk with the radiating ambulacral vessel. The floor of the brachial grooves is ciliated, and underneath each runs a radiating ambulacral vessel, together with a blood-vascular trunk, and a peculiar fibrillar "subepithelial band," which has been shown to be of a nervous nature. In the centre of the arm, between the calcareous skeleton and the water-vessel, are three tubular prolongations of the body-cavity. The middle and largest one of these (fig. 131, *ov*) contains one of the generative glands; while the upper and lower (the "sub-tentacular" and "cœliac" canals) are much smaller, and permit of a circulation of water derived from the body-cavity. The slender lateral "pinnules" carried by the arms have precisely the structure of the arms themselves as regards their internal anatomy.

The ciliated grooves on the ventral aspect of the arms are continued over the upper surface of the disc to reach the subcentrally or excentrically placed mouth; and the animal feeds upon the minute organisms conveyed to the mouth by the water-currents set up along these grooves. The mouth opens into a spirally-coiled alimentary tube, which forms the so-called

"visceral mass," and is wholly contained within the calyx, no diverticula from it extending into the arms.

The ambulacral system consists of a circumoral ring, without any direct communication with the exterior, and of the radiating ambulacral vessels which run along the brachial grooves. These give off the tube-feet, which are destitute of suckers, and are essentially respiratory in function. The circular ring communicates by five or more water-tubes with the body-cavity, to which the sea-water is freely admitted by minute pores in the body-wall; and the fluid which fills the ambulacral system is thus derived from the general cavity of the body.

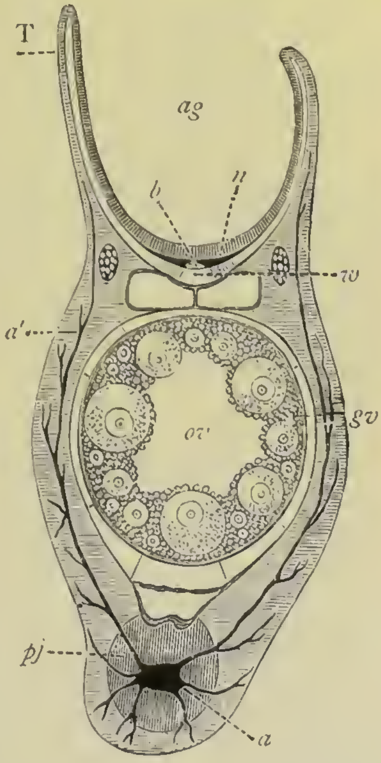

Fig. 131.—Cross-section of a pinnule of the Arctic Feather-star, magnified seventy-five times. (From Ludwig, after P. H. Carpenter.) *pj* Calcareous skeleton, containing the axial nerve-cord (*a*); *ag* Ambulacral groove; *n* Radial nerve; *b* Radial blood-vessel; *w* Ambulacral vessel; T, Tentacle; *ov* Ovary, with the sub-tentacular canal above, and the cœliac canal below; *gv* Genital blood-vessel.

The vascular system is extraordinarily developed, and its upper portion consists of an oral ring, a central plexus ("heart"), and of numerous branches connected with these. There is no aboral vascular ring, but the vessels become connected inferiorly with a singular quinquelocular structure known as the "chambered organ," which is contained within the centrodorsal plate of the calyx. The chambered organ is enclosed in a peculiar fibrillar sheath, the nature of which will be spoken off immediately, and it sends prolongations into all the arms, along canals contained within the skeleton of the latter, and also into the dorsal cirri.

In the Crinoids generally, the structure of the vascular system is much the same as it is in *Comatula* up to a certain point. Occupying the dorso-ventral axis of the body is a lobated structure homologous with the "heart" of the Asteroids, and like it consisting of numerous closely-packed vessels. Dorsally, these resolve themselves into a central group (of one or more), and five peripheral vessels, the latter expanding in the lower part of the calyx into the five chambers of the "chambered organ." In the Pedunculate Crinoids the chambers narrow again, and the group of vessels is continued down the central canal of the column. In *Pentacrinus*, which

has cirri at regular intervals, the five peripheral vessels expand in each cirrus-bearing joint into five dilatations, which thus give rise to a miniature "chambered organ," each chamber of which gives off a single vessel to a cirrus. In the body, the vascular axis is connected with (1) a large net-work of vessels round the alimentary canal, (2) an extensive plexus beneath the ventral surface of the disc, in which vessels arise that run out into the arms and enclose the genital glands, and (3) a plexus of convoluted tubes depending from the oral blood-vascular ring, in which the radial vessels of the arms originate (P. H. Carpenter).

The nervous system of the Feather-stars is also extraordinarily developed as compared with that of the other Echinoderms. As has been previously seen, there is found under the floor of each of the brachial grooves a fibrous nerve-band (fig. 131, *n*), which corresponds morphologically with one of the radiating nerve-fibres of a Star-fish. These radial nerves are connected with a circumoral ring, and appear to be wholly sensory in function. In addition to these, the "chambered organ," above spoken of in connection with the vascular system, is enclosed in a peculiar fibrillated sheath, which has been shown by Dr W. B. Carpenter to be of a nervous nature, and to have a motor function. This fibrillated sheath of the chambered organ gives off a series of radial prolongations or "axial cords" (fig. 131, *a*), which occupy a median canal within the skeleton of the arms, and which are also continued into the pinnules. In the stalked Crinoids the fibrillar nerve-sheath is likewise prolonged, along with the blood-vessels, into the central canal of the column or peduncle. No representative of this peculiar system of motor nerves is known in the ordinary Echinoderms.

Though free in its adult condition, the Feather-star passes through a stage of its development in which it is attached by a delicate jointed stalk to some foreign object (fig. 132). When first discovered in this condition it was supposed to be a distinct type of the Crinoids, and was described under the name of *Pentacrinus Europæus*. The *Comatula*, therefore, represents temporarily, in this stage of its development, the permanent condition of the Pedunculate Crinoids.

As regards the development of *Comatula*, the larva is at first cylindrical, with four transverse bands of cilia, a hinder tuft of cilia, and an alimentary canal furnished with a lateral aperture, its general aspect closely resembling that of the embryos of certain Annelides. The skeleton of the calyx is developed anteriorly, that of the column posteriorly, the former being the first to appear. In its early condition (fig. 132) the calycine skeleton consists of a row of five "basal plates" (*b*), which rest below upon the so-called "centrodorsal plate" (*cd*), and are succeeded above by a cycle of five "oral" plates (*o*), in the centre of which the permanent mouth is finally developed. Five "radial" plates (*r*) are next developed as a cycle between

the oral and basal plates; and to the radials are rapidly added the plates of the arms proper (the "brachial" plates). Inferiorly, the centrodorsal plate rests upon a short, jointed column (fig. 132, *c*), the lowest plate of which is expanded to form a disc of attachment; and the larva now passes into what is known as its "Pentacrinus stage." In the further progress of growth the arms increase in length, and the oral plates diminish in size and ultimately disappear. At the same time the centrodorsal plate increases in size, so as to enclose the basal plates, which in turn become fused with one another, and remain only as the so-called "rosette" on the upper surface of the centrodorsal. The latter also develops jointed cirri from its outer surface, and finally becomes detached from the next joint of the column below, when the animal enters upon its free stage of life.

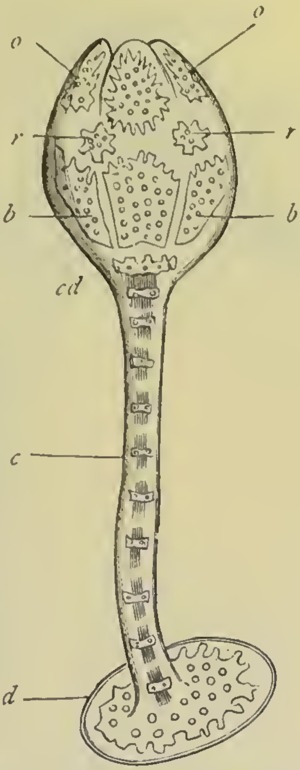

Fig. 132.—Larva of *Comatula* (*Antedon*) *rosacea*, enlarged (after Sir Wyville Thomson). *o o* Oral plates; *r r* Radial plates; *b b* Basal plates; *cd* Centrodorsal plate; *c* Column; *d* Disc of attachment.

As regards the essential features in their anatomy, the "Stalked" Crinoids do not differ materially from the "Sessile" forms of the group. More particularly, there is a substantial identity in structure in the two sections of the order as regards the form and arrangement of the alimentary canal, the ambulacral and vascular systems, and the nervous and reproductive organs. A Pedunculate Crinoid, such as *Pentacrinus* (fig. 133) or *Rhizocrinus* (fig. 136), consists of a cup-shaped body or "calyx," which encloses the principal viscera, and is furnished with a crown of pinnate "arms," and which is attached to some foreign object by means of a stalk or "column," composed of a number of calcareous pieces or "articulations." In some cases (as in *Apiocrinus*) the base of the "column" is considerably expanded. In other cases the column is simply "rooted by a whorl of terminal cirri in soft mud" (Wyville Thomson). The column may be extremely short, or even wanting, or may reach the extraordinary length of sixty or seventy feet. The whole column is composed of a series of ring-like or pentagonal joints, which are movably articulated with one another, and are furnished with special muscles, the joint surfaces often having a very elaborate structure, and the entire stem possessing in the living state a larger or smaller amount of flexibility. Very often more or fewer of the column-joints carry lateral jointed processes or "cirri"

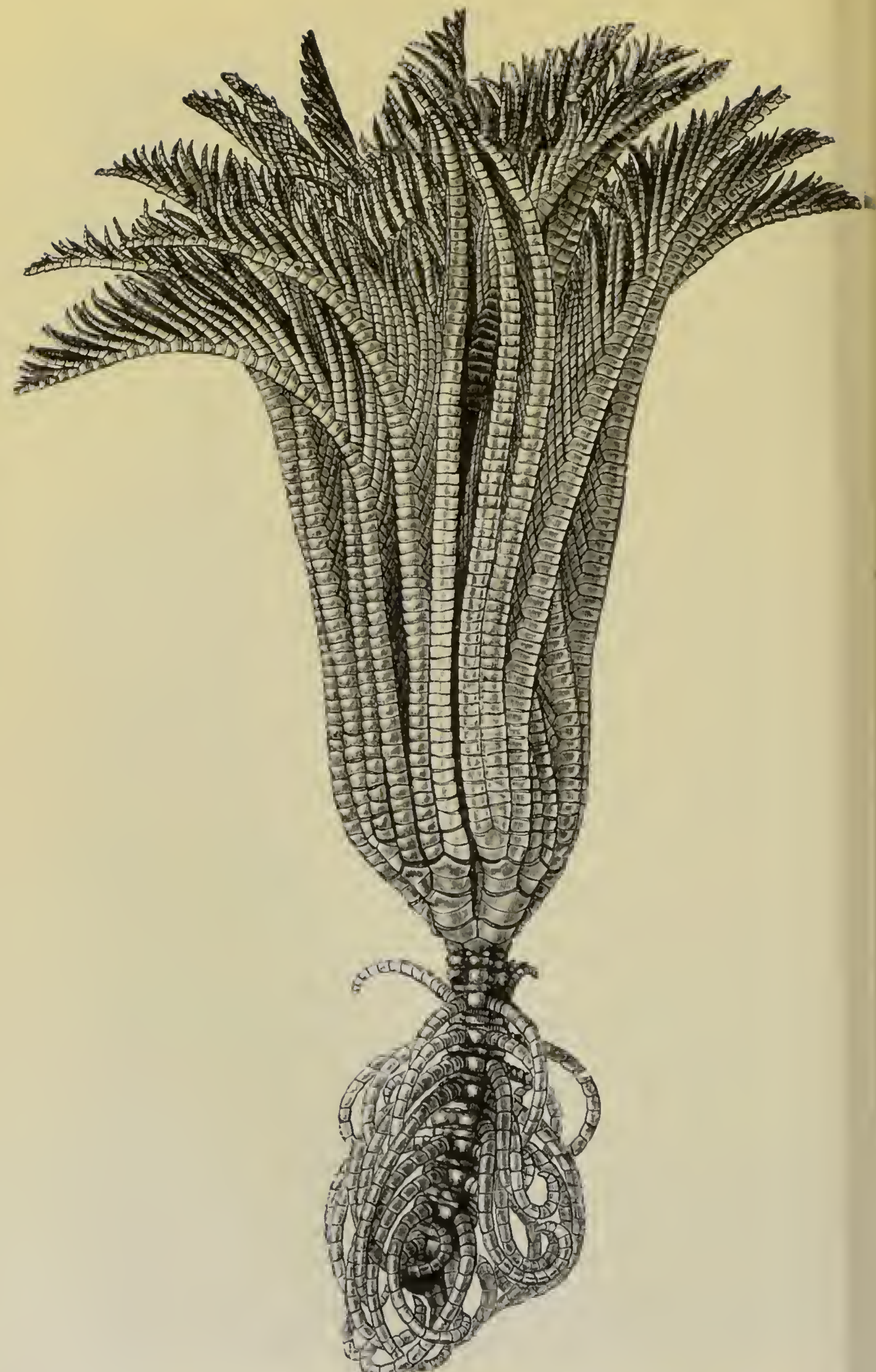

Fig. 133.—*Pentacrinus Macleayanus*, a living stalked Crinoid, slightly enlarged.

(fig. 133). Each joint of the stem is perforated centrally by a canal, which lodges an extension from the "chambered organ" and its fibrillar nerve-sheath.

The column carries at its summit the cup-shaped, pyriform, or bursiform body of the animal, which is termed the "calyx." As the column is produced from the aboral pole of the animal, it is the dorsal side of the calyx which is turned downwards, while the ventral or oral side is turned upwards. The dorsal or inferior side of the calyx is entirely enclosed in a series of polygonal calcareous plates closely articulated with one another, and having the following general arrangement (fig. 134). Resting directly upon the summit of the highest joint

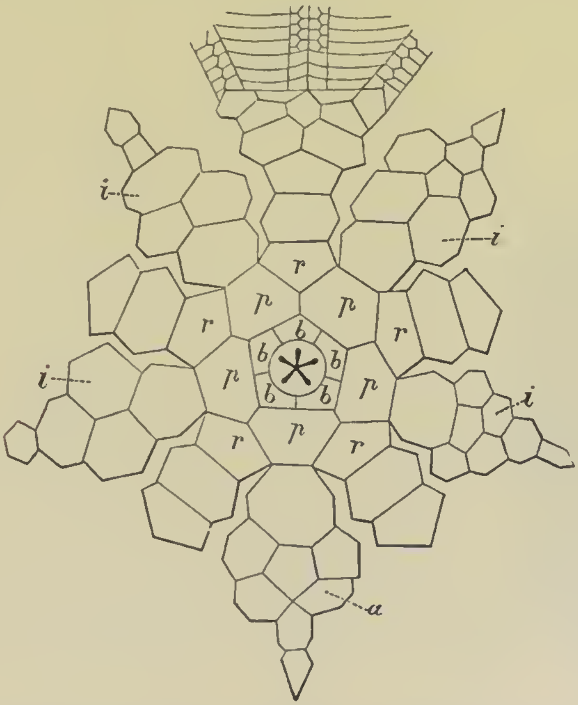

Fig. 134.—Diagram of the dissected calyx of *Rhodocrinus*, a "dicyclic" Crinoid, viewed from below (after Schultze). *b* Under-basals; *p* Basals; *r* First radials; *i* Inter-radials; *a* Anal plates.

of the column is the basal portion of the calyx ("basis"), consisting of a single or double row of articulated plates. In certain Crinoids ("monocyclic" forms) there is only a single row of plates in the basis, and these are known as the "basals." In other forms (termed "dicyclic") the basis consists of two circles of plates, in which case the plates of the lowest circle are known as the "under-basals" (fig. 134, *b*), while the plates

of the second circle are the "basals."* The "basals" in both cases are inter-radial in position, and correspond with the "genital plates" in the "apical disc" of the Echinoids. Succeeding to the basals, and alternating with them, are two or three cycles of plates, which are directly superimposed upon one another in longitudinal rows, and which form the foundations of the arms. These are known as the "radials" (fig. 134, *r*), and are termed "primary radials," "secondary radials," and "tertiary radials," according to their distance from the basals. The last radial plates, or those furthest from the column, give origin to the plates of the arms ("brachial" plates). The radial plates are arranged in a series of vertical columns, which radiate from the summit of the basals to the bases of the arms. Between the different columns of radial plates, however, there may be intercalated certain other smaller plates, which, from their position, are termed "inter-radials" (fig. 134, *i*); while one of the inter-radial spaces, corresponding with the anus, is usually much wider than the others, and is furnished with an additional series of calcareous pieces, which are termed "anal plates" (fig. 134, *a*). From the margins of the calyx, where the dorsal and ventral surfaces join one another, arise the "arms" (fig. 133). These are composed of numerous calcareous joints, movably articulated together, and furnished with proper muscles. The arms are usually primarily five in number, but they generally bifurcate almost directly after their origin, and the branches thus produced again subdivide, a crown of delicate feathery filaments being thus formed. The arms carry on their sides delicate jointed filaments or "pinnules" (fig. 135), the structure of which repeats that of the arms upon a smaller scale. The upper surface of the arms and pinnulæ is covered with a soft membrane, and below this are placed the reproductive organs. The generative organs are therefore not placed within the calyx, and it follows of necessity that there is no generative opening or "ovarian aperture" in the walls

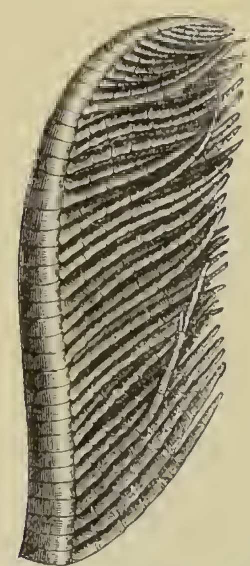

Fig. 135.—Portion of an arm of *Platycrinus*, showing the lateral pinnulæ.

* In the nomenclature of some writers, the plates of the dicyclic calyx are known respectively as the "basals" and "parabasals"; but the nomenclature of Dr P. Herbert Carpenter, employed above, undoubtedly expresses the true homologies of the monocyclic and dicyclic forms.

of the calyx. The ventral surfaces of the arms and pinnulæ are furnished with grooves, which in the living species are seen to be covered with vibratile cilia. The brachial grooves coalesce till they constitute five primary grooves, which are continued from the bases of the arms to the mouth. The action of the cilia gives rise to a constant current of sea-water, bearing organic matter in suspension; and this current proceeds from the brachial grooves to the mouth. In this way the animal obtains its food. As the bases of the arms are separated from the mouth by an intervening space, it follows that the brachial grooves are continued over the ventral surface of the calyx, till they reach the oral opening.

In all the living and in many extinct forms of Crinoids, the ventral surface of the calyx, usually covered by a leathery skin with scattered calcareous ossicles or plates, exhibits the central or sub-central aperture of the mouth, to which the ciliated brachial grooves converge. It also shows the excentrically-placed anus, often supported upon a tubular projection, or "proboscis." All those forms which have been grouped together by Dr P. Herbert Carpenter under the name of Neocrinoids, have the mouth and food-grooves thus exposed to view. On the other hand, in a large number of forms, mostly Palæozoic in their range, the upper surface of the calyx is covered by a dome of articulated calcareous plates, and does not exhibit either brachial grooves or a mouth-opening. The only opening which is seen in the ventral surface of the calyx is an excentric, often proboscidiform, aperture, which seems to be certainly the anus. The forms which exhibit this type of structure are known as the "Palæocrinoids"; and it has been shown that in these the brachial grooves are continued from the bases of the arms, as covered passages or tunnels, to a centrally-placed oral opening, the whole being concealed from view by the plated integument of the ventral surface of the calyx.

As regards the *distribution in space* of the Crinoids, the order is represented by comparatively few forms in recent seas, and these have mostly a very local distribution. The majority of living forms belong to the sessile division of the order, more than 150 species of *Comatula* (in the wide sense) being known, ranging from 82° N. lat. to Kerguelen's Land, but most abundant in the tropics. The different forms of *Comatula* have been described under various subordinate types (*Antedon*, *Actinometra*, *Comaster*, *Phanogenia*, &c.). On the other hand, the Pedunculate Crinoids, which abounded in the earlier periods of the earth's history, are now represented by fewer than forty

species, belonging to some half-a-dozen genera (*Pentacrinus*, *Rhizocrinus*, *Bathycrinus*, *Hyocrinus*, *Metacrinus*, and *Holopus*), ranging from less than 100 fathoms down to depths of 2500 fathoms. The most abundant recent Stalked Crinoids belong to the genus *Pentacrinus*. The little *Rhizocrinus Lofotensis* (fig. 136) occurs in the North Atlantic, and is of interest as being a modern representative of the Mesozoic family of the "Pear-Encrinites" (*Apiocrinidæ*).

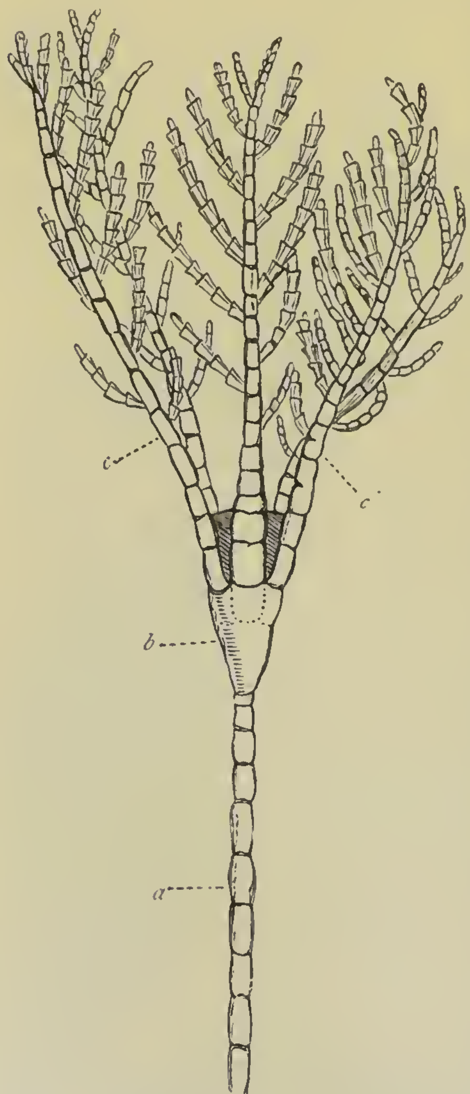

Fig. 136.—Crinoidea. *Rhizocrinus Lofotensis*, a living Crinoid (after Wyville Thomson), four times the natural size. *a* Stem ; *b* Calyx ; *c c* Arms.

As regards their *distribution in time*, the pedunculate Crinoids attained their maximum in the Palæozoic period, from which time they have gradually diminished down to the present day. On the other hand, the free Crinoids are comparatively modern, and seem to have reached their maximum at the present day. As has already been pointed out, the older forms of Crinoids (Palæocrinoids) differ in some important particulars from those which succeeded them. The order is well represented in the Silurian, Devonian, and Carboniferous rocks, but especially in the latter; many Carboniferous limestones (crinoidal limestones and entrochal marbles) being almost entirely made up of the columns and separate joints of Crinoids. In the Secondary rocks Crinoids are still abundant. In the Trias the beautiful "Stone-lily" (*Encrinus liliiformis*) is peculiar to its middle division (Muschelkalk). In the Jurassic period occur many species of *Apiocrinus* (Pear-encrinite), *Pentacrinus*, and *Extra-*

crinus. The Chalk also abounds in Crinoids, amongst which is a remarkable unattached form (the Tortoise-encrinite or *Marsupites*).

Of the non-pedunculate *Crinoidea*, which are a decided advance upon the stalked forms, there are comparatively few traces; but remains of forms (such as *Saccosoma* and *Solanocrinus*) allied to the recent *Comatulæ* have been found in the Jurassic and Cretaceous deposits.

ORDER CYSTOIDEA.—This order includes Echinoderms in which *the body* (*or* "*calyx*") *is spherical or ovate, and is enclosed in a case composed of more or fewer articulated calcareous plates, which are usually irregularly arranged, and do not exhibit perfect radial symmetry. Some of the plates of the calyx are perforated by pores or slits, communicating with internal tubular organs* ("*hydrospires*"), *the functions of which are partly respiratory and partly reproductive. A jointed column may be present or absent. The upper surface of the calyx shows radiating ambulacral grooves, a central oral aperture, and a lateral anal* (?) *opening, with sometimes a small ovarian* (?) *opening. Arms are imperfectly developed or wanting.*

The members of this order are all extinct, and are entirely confined to the Palæozoic period. The body (fig. 137) was,

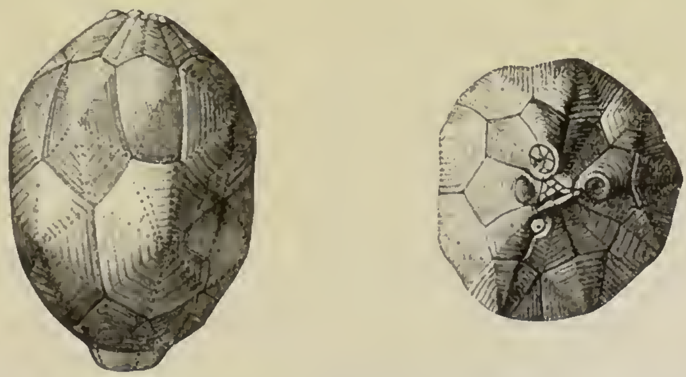

Fig. 137.—*Hemiscosmites pyriformis*, one of the Cystideans. The right-hand figure shows the upper surface of the calyx.

typically, more or less spherical or pyriform, and was protected by an external skeleton, composed of numerous polygonal calcareous plates accurately fitted together and enclosing all the viscera of the animal. The body was in most cases permanently attached to the sea-bottom by means of a jointed calcareous "column," or peduncle, but this was much shorter than in the majority of *Crinoids*, and was, rarely, altogether absent. Upon the upper surface of the body were two, sometimes three,

apertures, the functions of which have been a matter of considerable controversy. The central aperture may be regarded as certainly the mouth, as to it converge the ambulacral grooves, which correspond with the "food-grooves" of recent Crinoids. The lateral aperture was defended in many cases by a valvular pyramid of calcareous plates, and there seems little reason to doubt that it was anal in function. The third aperture is of small size, and only occasionally present. It may represent an ovarian aperture, but this cannot be regarded as certain.

The arms of the Cystideans are always imperfectly developed, and are placed in the neighbourhood of the mouth. They vary from two to five in number, are often very short, and are never branched. Only in one form (*Comarocystites*) do they carry lateral pinnulæ.

The most remarkable organs in the Cystoids are the so-called "hydrospires." These have the form of folded lamellar tubes, which are suspended in the body-cavity internally, and communicate with the exterior by pores or slits in the plates of the test. The hydrospires may be compared with the folded sacs or "bursæ" of the Ophiuroids, into which the generative ducts open internally, and which open externally by the slit-like "genital clefts." Like the "bursæ" of the Ophiuroids, the "hydrospires" may be supposed to be partly respiratory and partly reproductive in their function.

As regards their *distribution in time*, the Cystideans are exclusively confined to the lower portion of the Palæozoic series, being especially characteristic of the Ordovician rocks. The last known forms of the order occur in the Devonian rocks.

ORDER BLASTOIDEA.—This order comprises Echinoderms in which *the body ("calyx") is pyriform, ovate, or globular, and is attached by a short jointed peduncle, which is in some cases wanting. The body exhibits complete radial symmetry, and is enclosed in an armour of articulated calcareous plates. The upper surface exhibits five petaloid ambulacra, which radiate from the mouth, this latter being superior and central, and being concealed by a vault of small calcareous plates, as also are the ambulacral grooves themselves. Small jointed appendages or "pinnules" are attached to the sides of the ambulacral grooves. "Hydrospires," opening by five or ten openings placed round the mouth, are present.*

The members of this order, like those of the preceding, are all extinct, and are entirely confined to the Palæozoic period. The body or "calyx" (fig. 138) is generally pyriform or ovate, and is enclosed in an extremely complicated test, the details of which cannot be here discussed. The dorsal side of the calyx is formed by three "basals," five "radials," and five

"inter-radials"; and there may or may not be a short jointed "column," by which the body was attached to the sea-bottom. The upper surface of the body exhibits five wide, petal-shaped

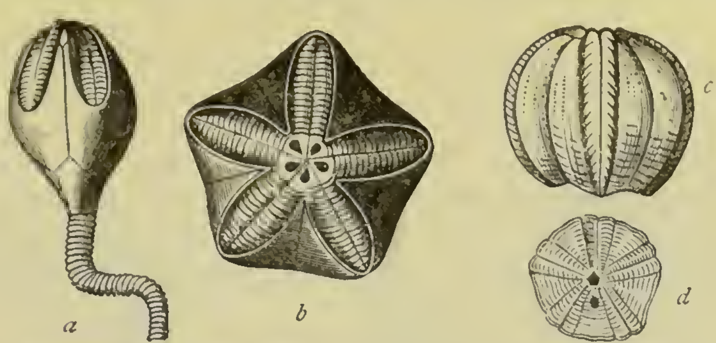

Fig. 138.—Morphology of Blastoidea. *a Pentremites pyriformis*, viewed sideways, showing a portion of the column; *b* Summit of the calyx of *Pentremites cervinus*, showing the ambulacral areas and the apical apertures; *c* Side view of *Granatocrinus melonoides*; *d* Summit of *Granatocrinus neglectus*. (Figs. *a* and *b* are of the natural size; *c* and *d* are slightly enlarged.) After Hall, and Meek and Worthen.

ambulacra, each of which is centrally grooved. These undoubtedly correspond with the brachial grooves ("food-grooves") of the upper surface of the calyx of the Crinoids, and, like the latter, doubtless served to convey currents of water to the centrally-placed mouth. In perfectly preserved specimens, both the mouth and the ambulacral grooves are found to be covered over with a plated membrane of small calcareous ossicles. On each side of each ambulacral groove was fixed a single or double row of small jointed "pinnulæ." The "hydrospires," lastly, have the form of folded lamellar tubes, which are essentially the same in structure as they are in the Cystoids, and probably the same in function. The hydrospires of the Blastoids differ, however, from those of the Cystideans in many important particulars as regards their construction and communication with the exterior. They are usually arranged in ten groups, connected with tubes running underneath the ambulacra, opening externally by pores on the sides of the ambulacral grooves, and also communicating with the exterior by five or ten comparatively large openings ("spiracles") placed round the mouth.

As regards their *distribution in time*, the Blastoids are not only exclusively Palæozoic, but have a limited range, the earliest forms appearing in the higher part of the Silurian formation, while the last are found in the Carboniferous Limestone. It is in the latter formation that the Blastoids attain their maximum development. The most familiar genus is *Pentremites*.

CHAPTER XX.

HOLOTHUROIDEA.

ORDER HOLOTHUROIDEA.—*Vermiform or slug-like Echinoderms, with a leathery skin, in which calcareous grains, plates, or spicules are developed. The mouth and anus are more or less completely terminal in position. The circumoral ambulacral vessel gives off prolongations to retractile tentacles placed round the mouth; and the madreporite commonly does not communicate directly with the exterior. The larva has no pseudembryonic skeleton.*

The members of this order are commonly known as "Sea-cucumbers," "Trepangs," or "Bêches-de-mer," and are the most worm-like of all the Echinoderms, presenting considerable resemblances to the Spoon-worms (*Gephyrea*). The body is elongated and vermiform, or sometimes slug-shaped, often showing bilateral symmetry to a greater or less extent. The mouth and anus are placed at the anterior and posterior ends of the body respectively, though in some forms shifted to some extent towards the ventral side; and the mouth is surrounded by a crown of tentacles (fig. 139).

There is no proper "test," but the skin contains numerous isolated calcareous bodies, of special forms in different types. These calcareous structures may be globular, wheel-shaped, spicular, anchor-shaped, &c., and in rare cases (as in *Psolus*) have the form of imbricated scales, constituting a kind of external case. Within the proper skin is a muscular layer, composed of an outer circular and an inner longitudinal stratum. The longitudinal layer is divided into five principal bands, which are inserted anteriorly into a calcareous circum-oral ring, and each of which is longitudinally bisected by a radiating ambulacral vessel (when this exists) and by a radial nerve-cord. The calcareous ring just spoken of consists of a series of plates, generally ten in number, surrounding the gullet, of which five may be regarded as corresponding with the "auriculæ" of the Echinoid test; but the entire structure is very imperfectly developed in some Holothurians.

The tentacles which surround the mouth (fig. 139) are retractile hollow processes, containing prolongations from the circular ring of the ambulacral system. The tentacles vary much in form, being sometimes digitate or feather-like, but being more usually either branched in an arborescent manner (as in the *Dendrochirotæ*), or provided with shield-like exten-

sions (*Aspidochirotæ*). In function, the tentacles may be considered as largely connected with respiration.

As regards the digestive system, the toothless mouth opens into a funnel-shaped pharynx, which in turn passes into the proper alimentary canal. This continues with unaltered width, usually describing various convolutions in its course,

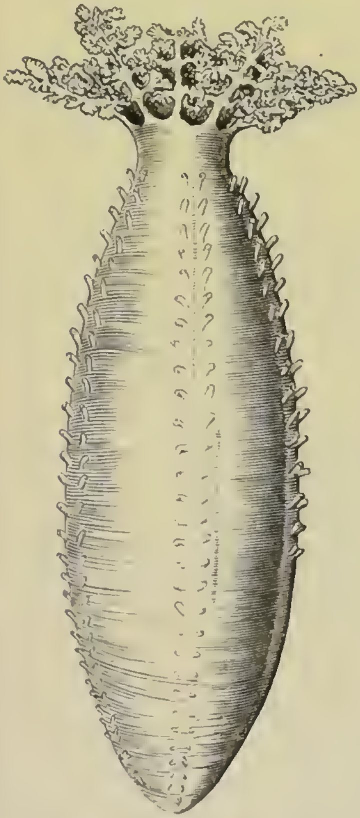

Fig. 139. — *Cucumaria frondosa*, showing the crown of feathery tentacles round the mouth and the rows of tube-feet.

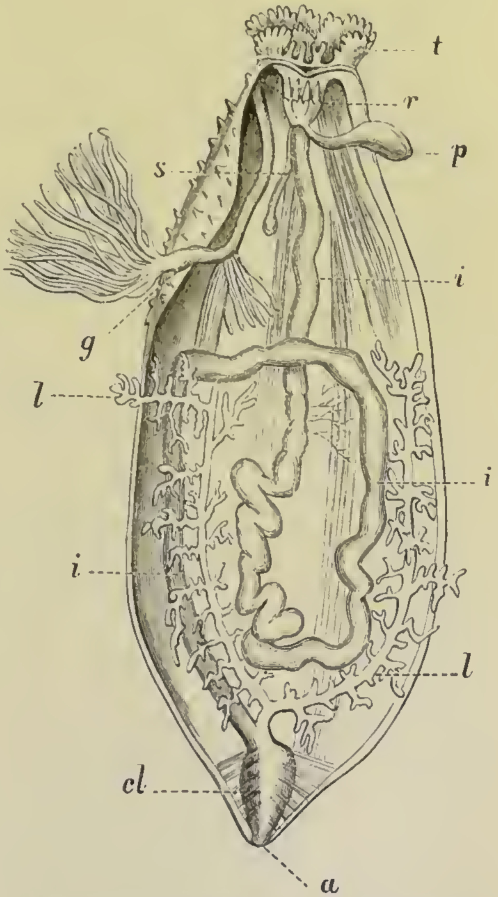

Fig. 140.—*Holothuroidea*. Semi-diagrammatic longitudinal section of a Holothurian. *t* Tentacles; *r* Calcareous ring at the base of the tentacles; *p* Polian vesicle; *s* Sand-canal; *i i i* Alimentary canal; *g* Duct of the reproductive organs; *cl* Cloaca; *a* Anus; *l l* Respiratory tree.

to the opening of the anus at the hinder end of the body. In all those forms, however, which possess a "respiratory tree," the alimentary canal terminates in a large muscular chamber or "cloaca" (fig. 140, *cl*), which opens on the exterior by the anus. The alimentary canal is connected with the wall of the body by a delicate membranous "mesentery"; and the body-

cavity is filled with a watery fluid containing floating corpuscles. This fluid is kept in motion by the cilia covering the external surface of the intestine and other internal organs.

The vascular (pseudohæmal?) system consists of a principal dorsal and ventral vessel running along opposite sides of the intestine, together with an oral plexus, from which proceed radial vessels; but in most cases there is no central plexus or "heart," such as occurs in most Echinoderms.

Respiration is carried on partly by the tentacles, and partly by the ciliated mesentery and lining of the body-cavity. In many Holothurians — hence termed *Pneumonophora* — there are in addition two branched tubular organs, which spring posteriorly from the cloaca and extend forwards into the body-cavity, constituting the so-called "respiratory tree" or "water-lungs" (fig. 140, *ll*). Water is admitted to the respiratory tree from the cloaca, and gains access to the body-cavity by minute pores in the ends of the branches of the tree. The so-called "Cuvierian organs" are peculiar, thread-like, or tubular structures, opening into the cloaca or into the stem of the respiratory tree, and usually regarded as performing some excretory function.

The ambulacral system varies greatly in its development, but the circular oral ring, with its branches to the tentacular crown, is always present. In many Holothurians there is only a single "Polian vesicle," often of great length (fig. 140, *b*), attached to the circular ring; but there may be two, five, or many vesicles. The stone-canal is, typically, a short diverticulum of the ring-canal, extending into the body-cavity, and terminating in a dilated extremity or "madreporite," which is strengthened by calcareous spicules, and covered by epithelium. In these cases, therefore, the stone-canal (fig. 140, *s*) hangs down freely into the body-cavity, and the fluid which fills the ambulacral vessels is derived from the body-cavity. In other forms, however (viz., in the *Elasipoda*), the stone-canal terminates in a madreporite which is either connected with the dorsal integument in the middle line, or actually opens on the surface. When fully developed, the oral ring gives off backwards five radiating ambulacral vessels, which divide the body into an equal number of longitudinal segments or lobes. The tube-feet given off by the radiating vessels may be irregularly scattered, or each of the latter may give off a double row of tube-feet (as in *Cucumaria*, fig. 139), which perforate the integument, their free ends terminating in suckers, and their bases being provided with internally-placed "ampullæ." In such cases, the rows of tube-feet are divisible into a ventrally-

placed series of three rows ("trivium"), and a dorsally-placed series of two rows ("bivium"). In most cases, the tube-feet of the dorsal rows are less developed than those of the ventral rows, or they may be aborted altogether (as in *Psolus*); while in the *Synaptidæ* there are no radial vessels at all. Lastly, the tube-feet, when present, may terminate simply in conical ends and may be devoid of suckers.

The nervous system has the form characteristic of the Echinoderms, consisting of an oral ring, sending backwards five branches, which accompany the radiating ambulacral vessels.

The reproductive organs in all Holothurians have the form of a number of cæcal tubes, which lie freely in the body-cavity, and unite to form a single excretory tube, opening externally on the upper surface within or without the tenta-

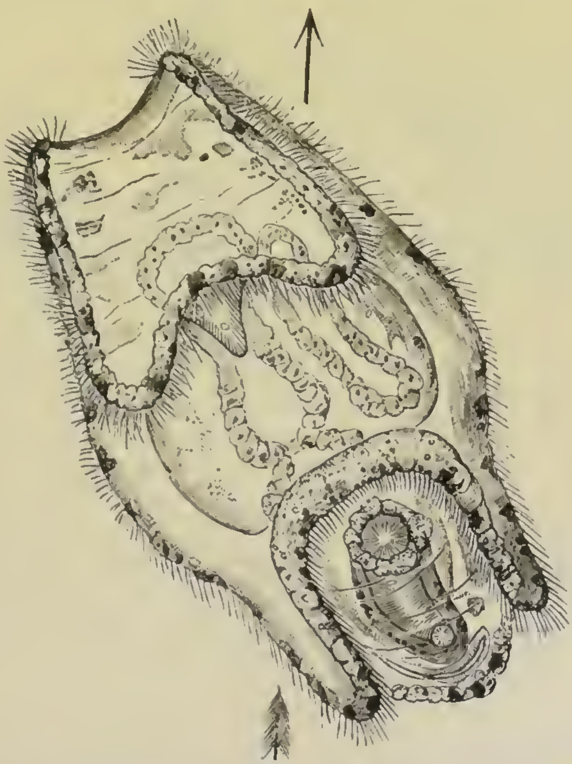

Fig. 141.—Larva of *Holothuria tubulosa* in its natural position, magnified. (After Selenka.) The arrow indicates the axis of rotation.

cular crown. Generally there is a right and left bundle of generative tubes, but sometimes only those on the left side are developed.

In some Holothurians development is direct, the young being carried about by the mother, adhering to the tube-feet

of the dorsal ambulacra. More usually there is a metamorphosis, though this is not so extensive as in the Echinoids and Asteroids. The larval Holothurian exhibits bilateral symmetry, and swims about by means of a continuous longitudinal ciliated band (fig. 141), which enables it to rotate in a nearly vertical position, with the mouth at its upper end and the anus at its lower end. After a time the ciliated band breaks up into a series of transverse rings, and the embryo becomes barrel-shaped, when it is known as an "*Auricularia.*" At this stage the stone-canal opens on the exterior; but this connection is in most cases lost with advancing development. Ultimately the body elongates, the tentacles appear, and the adult Holothurian is gradually produced. The embryo resembles that of the Star-fishes in having no provisional skeleton.

There are three principal divisions of the Holothurians. In one of these divisions—the so-called *Pedata*—are comprised most of the ordinary Holothurians, such as *Holothuria* and *Cucumaria* (fig. 139), all of which possess tube-feet or pedicels, and have a "respiratory tree." The oral tentacles may be arborescent (*Dendrochirotæ*), or shield-like (*Aspidochirotæ*). The body is fusiform, or pentagonal, or flattened below and convex above, with more or less marked bilateral symmetry.

In a second great section—the so-called *Apoda*—there are no tube-feet, and the body is worm-like or fusiform, without any clear demarcation between the dorsal and ventral surfaces, while the tentacles are mostly pinnate or digitate. Some of these Apodous Holothurians (*Apneumona*), such as *Synapta* and *Chirodota*, have no respiratory tree and no radial ambulacral vessels. On the other hand, forms like *Molpadia* possess a respiratory tree (*Pneumonophora*), and also have radiating ambulacral vessels. The *Synaptæ* are singularly worm-like, and burrow in sand or mud, which they swallow for the purpose of obtaining any disseminated nutrient particles. They often form a kind of protective case or tube of sand-grains, and the integument is furnished with innumerable anchor-shaped spicules (fig. 142), attached to special "anchor-plates." In *Chirodota*, the skin is provided with microscopic calcareous wheels in place of anchors.

Fig. 142.—Anchor-shaped spicules of *Synapta*, and the plates to which these are attached. Magnified greatly.

The third great section of Holothurians has been termed by Théel *Elasipoda*, and comprises some of the most abnormal types of the order. The body in these forms (fig. 143) is more or less bilaterally symmetrical, often slug-like, with a flat or concave ventral side, and a convex dorsal surface. Very often the dorsal surface carries long, conical, non-retractile tentacular processes. The skin is furnished with calcareous plates, wheels, or spicules. The madreporite is single, never depending freely into the body-cavity, but either fixed to the dorsal integument in the middle line, or piercing the body-wall, and communicating with the exterior by one or several pores. A respiratory tree is wanting, and the ambulacral ampullæ are often much modified.

As regards their *distribution in space*, the Holothurians enjoy a nearly world-wide range. The ordinary types (*Pedata* and *Apoda*) are mostly inhabitants of shallow seas, or live

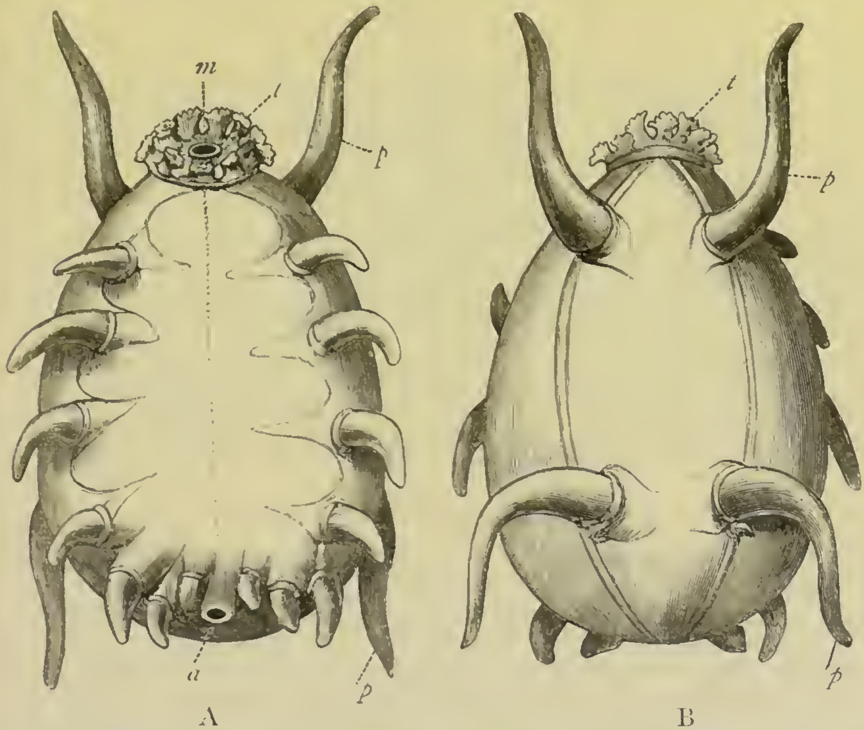

Fig. 143.—*Scotoplanes globosa*, an Elasipodous Holothurian, (after Théel). A, Ventral side; B, Dorsal side. *m* Mouth, surrounded by the tentacles (*t*); *p* Dorsal non-retractile processes; *a* Anal opening.

between tide-marks. Some of the larger forms occur in vast abundance on the coral-reefs of the Pacific, one species (*Holothuria argus*) being largely used for food. The *Elasipoda*, on the other hand, are essentially deep-sea forms, extending their range to 2600 fathoms, and appearing to be represented in all seas.

With regard to their *distribution in time*, little can be stated, as the hard parts of the Holothurians are mostly microscopic in size, and therefore naturally difficult of detection. Structures which have been regarded as referable to the calcareous plates of *Chirodota* occur in the Carboniferous Limestone, and similar bodies are found in the Jurassic rocks; while the plates of *Psolus* have been detected in Post-Tertiary deposits in Bute.

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ANNULOSA.

CHAPTER XXI.

1. GENERAL CHARACTERS OF THE ANNULOSA. 2. DIVISIONS OF ANNULOSA. 3. GENERAL CHARACTERS OF THE SCOLECIDA. 4. CHARACTERS OF THE TÆNIADA.

SUB-KINGDOM ANNULOSA.—The Annulose animals are characterised by the possession of *a body which is usually more or less elongated, and is always bilaterally symmetrical, instead of being radially disposed. Very commonly the body is divided into similar* (*homonomous*) *segments, which may be definite or indefinite, and are arranged along an antero-posterior axis. Lateral appendages may be absent or present, and when present, are symmetrically disposed. A nervous system is present, and consists of one or two ganglia placed in the anterior part of the body, or of a ventrally-placed double gangliated chain.*

The association of the *Scolecida* with the normal Annulose animals renders necessary an exceedingly general, and therefore correspondingly vague, definition of the sub-kingdom *Annulosa.* The sub-kingdom may, however, be divided into the following three primary sections, each of which admits of being characterised in a sufficiently definite manner:—

I. *Scolecida.*—This division includes the parasitic worms (*Entozoa*), the Wheel-animalcules, and some allied forms, and is characterised by having an elongated or a flattened body, which may have an annulated integument, but which is not at all, or but imperfectly segmented. A water-vascular system is present, but is not concerned with locomotion. There is no true blood-vascular system, and the nervous system consists of one or two cephalic ganglia, and never has the form of a gangliated ventral chain. Lateral appendages are almost universally wanting.

The *Scolecida* were formerly placed by Huxley along with the *Echinodermata* in a special sub-kingdom (*Annuloida*); and no doubt can be entertained as to the reality of the relationships between these two groups of animals. On the other hand, many and close points of affinity unite the higher *Scolecida* with the Ringed Worms (*Annelida*); and some systematists unite the *Scolecida* and *Anarthropoda* in a common sub-kingdom, to which they restrict the Linnean name of *Vermes*.

II. Anarthropoda.—This division includes the Spoon Worms (*Gephyrea*), the Ringed Worms (*Annelida*), and the Arrow Worms (*Chætognatha*), and is characterised by the fact that the body is composed of a number (often indefinite) of similar or nearly similar segments arranged longitudinally. A "pseudohæmal" system of vessels is generally present. The nervous system is placed ventrally, and consists typically of a double chain of ganglia, united by longitudinal commissures, and forming an œsophageal collar. Cilia are generally developed. Lateral locomotive appendages are usually present, but are never jointed or articulated to the body.

III. Arthropoda.—This division includes the Crustaceans, (*Crustacea*), the Spiders, Scorpions, &c. (*Arachnida*), the Centipedes and their allies (*Myriopoda*), and the Insects (*Insecta*). The body (fig. 144) is composed of a series (usually definite)

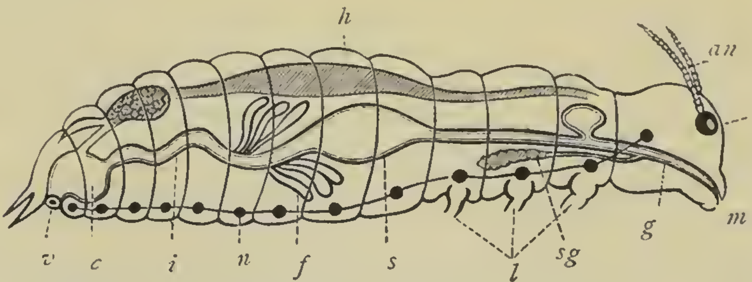

Fig. 144.—Diagram of the anatomy of an Insect. *an* Antennæ; *e* Eye; *m* Mouth; *g* Gullet; *sg* Salivary gland; *s* Stomach; *f* Tubes representing the kidneys; *i* Intestine; *c* Chamber (cloaca) into which the intestine opens; *v* Vent; *h* Heart; *n* Nervous system; *l* Bases of the legs.

of distinct rings or "somites," arranged along a longitudinal axis. A true blood-vascular system is normally present, and the heart is placed dorsally. The nervous system consists primitively of a double chain of ganglia, placed ventrally, and traversed anteriorly by the œsophagus. Limbs are almost always present, and are jointed and articulated to the body. The integument is more or less extensively hardened by the deposition in it of chitine, with or without salts of lime; and ciliated epithelium is not developed.

THE SCOLECIDA.

The name of *Scolecida* was proposed by Professor Huxley * for the reception of the *Rotifera*, the *Turbellaria*, the *Trematoda*, the *Tæniada*, the *Nematoidea*, the *Acanthocephala*, and the *Gordiacea*. Of these the *Rotifera* stand alone; whilst the *Turbellaria*, *Trematoda*, and *Tæniada* constitute the division of the *Platyelmia* (Flat Worms); and the *Nematoidea*, *Acanthocephala*, and *Gordiacea* make up the *Nematelmia* (Round Worms or Thread-Worms). The term *Entozoa* has acquired such a general currency that it is necessarily employed occasionally, but it has been used in such widely different senses by different writers, that it would be almost better to discard it altogether. It certainly cannot be used as synonymous with *Scolecida*, many of these not being parasitic at all. It will therefore be employed here, in a restricted sense, to designate those orders of the *Scolecida* which are internal parasites, comprising the *Trematoda*, *Tæniada*, *Nematoidea* (in part), *Acanthocephala*, and *Gordiacea*. The *Turbellaria* and *Rotifera*, with a section of the *Nematoidea*, lead a free existence, and are not parasitic within other animals.

The *Scolecida* are defined by the possession of a "water-vascular system," consisting of branched tubes, filled with a watery fluid, and usually communicating with the exterior. There is no proper blood-system, and the nervous system consists typically of a double ganglion or a pair of ganglia. The body is usually unsegmented, rarely imperfectly segmented; and lateral appendages are absent (except in some Rotifers).

DIVISION I. PLATYELMIA.—This section includes those *Scolecida* which possess a more or less flattened body, usually somewhat ovate in shape, and not exhibiting anything like distinct segmentation. The division includes two parasitic orders—the *Tæniada* and the *Trematoda*,—and one non-parasitic order—viz., the *Turbellaria*. A sub-order, however, of this last, the *Nemertidæ*, does not conform to the above definition; but its other characters are such as to forbid its removal.

ORDER I. TÆNIADA (*Cestoidea*).—This order comprises the internal parasites called Tape-worms (Cestoid worms), and the old order of the "Cystic Worms" (Cystica); the latter

* More recently ('A Manual of the Anatomy of Invertebrated Animals,' 1877) Professor Huxley has abandoned the division of the *Scolecida*, and has separated its members into two sections (*Trichoscolices* and *Nematoscolices*).

being now known to be merely immature forms of the Tapeworms.

The *Tæniada* are Scolecids in which *the body of the adult is elongated and composed of flattened joints, the anterior extremity ("head") armed with hooklets, or suckers, or both combined. There is no mouth or alimentary canal, and the young pass through a metamorphosis. The mature animal is hermaphrodite.*

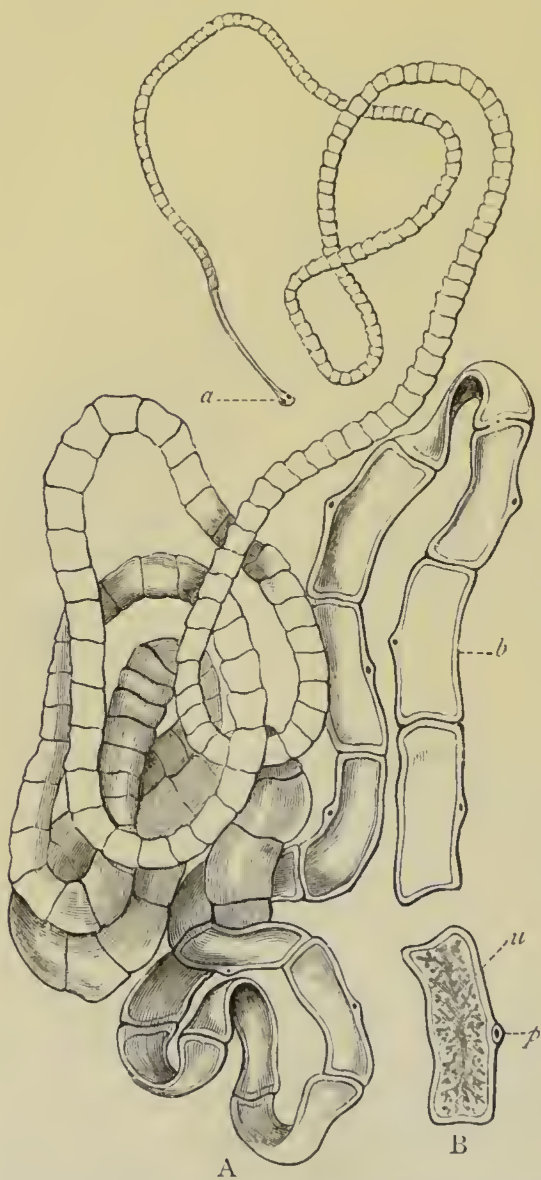

Fig. 145.—A, *Tænia solium*, of the natural size: *a* "Head" or "nurse"; *b* One of the proglottides from the sexually mature part of the worm. B, A single mature proglottis of the same, showing the genital pore (*p*) and the branched uterus (*u*).

The adult Tapeworms are found inhabiting the alimentary canal of Vertebrate animals of various kinds. In its mature condition, a Tapeworm usually consists of a minute rounded anterior extremity or "head" (fig. 145, *a*), followed posteriorly by a larger or smaller number of loosely-connected pieces or "joints." These latter, usually called "proglottides," have the appearance of being segments, but are in reality buds produced from the head, and containing the reproductive organs. The buds nearest the head are the ones last produced, and are imperfect; hence the body is comparatively narrow in front; but as we proceed backwards from the head, the proglottides gradually widen out, and become

ultimately mature. In certain forms (as, for example, in the simple *Caryophyllæus* of the Carp) the animal consists only of the head, which contains the generative organs, there being thus no joints or "proglottides." In the *Ligulæ* of Fishes, Amphibians, and Water-birds, again, the body is annulated, and contains longitudinally-disposed groups of reproductive organs, but proper proglottides are not developed.

An ordinary tape-worm, however, consists of the "head" and a variable number of reproductive buds or "proglottides," these latter being ultimately detached from the general mass or "strobila." To the aggregate of the head and joints we must apply the term "individual"; but the joints have also a certain amount of individuality, since they may live, and even increase in size, after detachment from the parent "strobila." As the larval tape-worm has also, in some instances, the power of producing new beings by gemmation, each of which may become ultimately developed into a "strobila," the individuality of the tape-worms is of a very complex type.

As regards the anatomy of a typical tape-worm, the minute rounded anterior extremity or "head" (figs. 146, *e*, and 147, B)

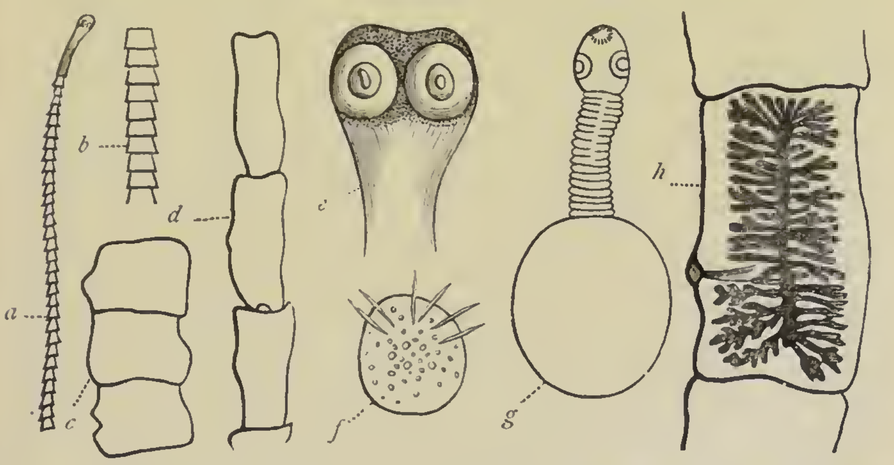

Fig. 146.—Morphology of *Tæniada*. *a* Head and a few following segments of *Tænia mediocanellata*; *b* A few segments of the same further removed from the head; *c* and *d* Segments progressively further removed from the head,—all of the natural size; *e* Head of the same, enlarged; *h* A single proglottis of the same, with its branched uterus and lateral genital pore, enlarged two diameters; *f* Embryo of *Tænia bacillaris*, with six hooklets; *g Cysticercus cellulosæ*, with its hooklets and suckers, its wrinkled neck, and its caudal vesicle, enlarged. (After Leuckart, Van Beneden, and Weinland.)

is fixed to the mucous membrane of the intestine of the "host" by muscular cup-like or slit-like suckers, two or four of these organs being present. In the so-called "armed" tape-worms, the head carries in addition to the suckers a circlet of horny

hooks, the bases of which are lodged in secreting sacs, and which are usually arranged in a closely-set double row. There is a thin chitinous cuticle, underlaid by a fibrous corium, and by longitudinal and transverse muscular fibres, and the integument contains numerous minute refracting bodies, known as "calcareous corpuscles." No mouth is present, nor are there any digestive organs, the nutrition of the animal being entirely carried on by imbibition through the skin. The head contains two minute nerve-masses (ganglia?), which are connected by a transverse cord, and send two longitudinal branches backwards. The "water-vascular system" begins in the head, and consists of two principal trunks, which run down the sides of the body, communicating with one another at each articulation by means of a transverse vessel, and opening in the last joint into a contractile vesicle with a terminal pore. The water-vessels are ciliated internally, and connected with the main vessels, are minute branching tubes, which ramify through the tissues.

The "head" or "nurse" contains no other organs than those enumerated above, the reproductive organs being developed in the joints or "proglottides," which the head produces posteriorly by a process of gemmation. After the production of the first joint, each new proglottis is intercalated between the head and the articulation, or articulations, already formed; so that the joints nearest the head are those latest formed, and those furthest from the head are the most mature. Hence the portion of the body just behind the head is narrow and thread-like, and it only gradually widens out, till we reach a point where the joints are "ripe," and have their full width. Each proglottis contains a lateral canal of the water-vascular system, accompanied by a lateral nerve; and each, when mature, contains the male and female generative organs (figs. 146, *h*, and 147, A). The male organs consist of numerous grape-like testicular sacs, the ducts of which ultimately unite, to open, at the "genital pore," in a sac containing a filamentous protrusible "cirrus" or penis. The female organs of the proglottis are very complex, consisting of an ovary, with various accessory glands, a greatly-branched dendritic "uterus," usually filled with ova, and a sac ("spermatheca") in which the spermatozoa are stored up. The vagina terminates at the "genital pore," and impregnation is effected between the several proglottides of the same worm. The position of the "genital pore" is usually on the lateral margin of the proglottis (fig. 145, *p*), when the pores may be all on one side of the strobila, or may be placed alternately on different sides of successive proglottides, as is the case in the common Pork tape-worm and Beef tape-

worm. In the Russian tape-worm (*Bothriocephalus latus*) the generative pores are on the flat sides of the joints (fig. 147, F).

The above gives an outline of the organisation of one of the ordinary tape-worms in its fully mature condition; and we have next to briefly consider the developmental processes by which this condition is reached. The "armed" tape-worms—*i.e.*, those in which the head is furnished with a crown of hooklets—inhabit the alimentary canal of carnivorous or omnivorous Mammals and Birds. The "unarmed" tape-worms—*i.e.*, those in which the head has suckers only, without hooks—are found in the same situation in vegetable-eating or omnivorous Mammals, as well as in some Reptiles, Amphibians, and Fishes. In most cases, the same species of tape-worm, in its adult state, is not found in more than one species of animal. In other cases, the same form may infest more than one species; while it is common for the same "host" to be liable to the attacks of more than one kind of adult tape-worm. In all cases alike, however, there is the peculiarity that the eggs of the proglottides cannot develop themselves in the intestine of the animal in which the adult tape-worm is found. In all cases, therefore, the egg requires to be expelled from the body of the original host, and to gain access to the body of some other animal, within which it can undergo the earlier stages of its development. In the case of every tape-worm, therefore, we have to deal with *two* hosts—viz., (1) the animal which lodges the adult worm, and which may be termed the "final host"; and (2) the animal in which the young or larval form is developed, and which may be called the "intermediate bearer." In rare cases—by accident, as it were—the same animal may act in both of these capacities. Thus, occasionally, man not only acts as the "final host" to the *Tænia solium*, but also serves as "intermediate bearer." As a rule, however, the "final host" and the "intermediate bearer" are not only different animals, as individuals, but belong to different *species* of animals. Thus, while *man* acts normally as the "final host" to the *Tænia solium*, the *pig* officiates normally as the "intermediate bearer" to the same. Moreover, there is generally this relation between the final host and the intermediate bearer, that the latter is liable to be eaten by the former.

The ordinary course of development in one of the typical tape-worms is briefly as follows:—

As has just been mentioned, the ova of the tape-worm cannot develop themselves within the intestine of the "final host," but require to be swallowed by some animal other than the one inhabited by the mature worm, and thus to gain access to the

stomach of the latter. To render this possible, the "ripe" proglottides, filled with fertilised ova, are successively detached from the hinder end of the mature tape-worm, and are expelled from the intestine of the final host along with the fæces. After their discharge in this way, the proglottides may for some time retain their vitality, and may possess some power of movement, in some cases increasing in size and only first becoming fully developed after their expulsion from the body of the final host. In all cases, however, the proglottides ultimately die and decompose, thus liberating the contained ova, which are protected from injury by ordinary mechanical or chemical agencies by the possession of a thick horny capsule (fig. 147, C). In this

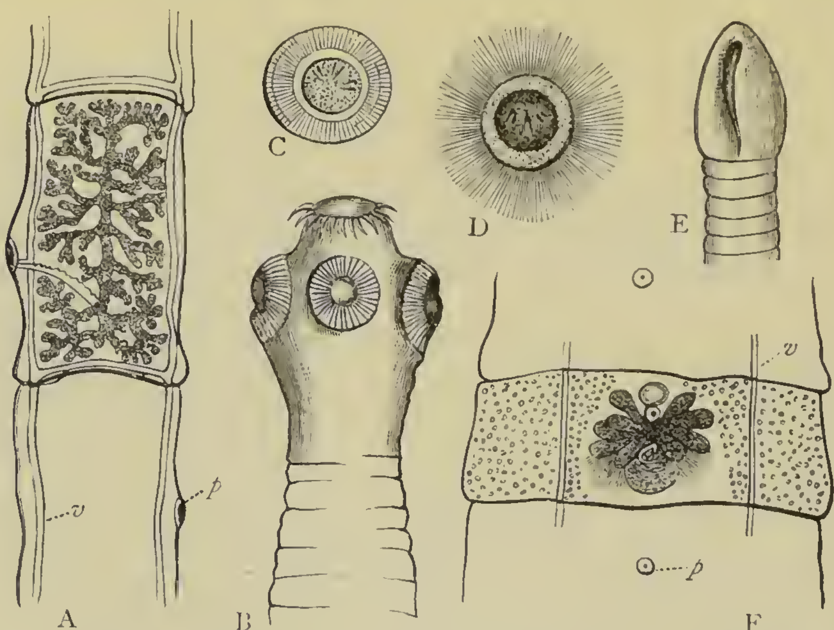

Fig. 147.—Morphology of *Tæniada*. A, Proglottides of *Tænia solium*, showing in one joint the branched uterus; B, Head of *Tænia solium*; C, Ovum of *Tænia solium*, showing the minute six-hooked embryo enclosed in a horny shell; D, Six-hooked embryo of *Bothriocephalus latus*, enclosed in a ciliated integument; E, Head of *Bothriocephalus latus*, showing one of the two slit-like suckers; F, Proglottides of *Bothriocephalus latus*, showing the rosette-shaped uterus, and the position of the generative pores: *v* Water-vessel; *p* Generative pore. All the figures are enlarged, C and D greatly so. (B, D, and F are after Leuckart.)

stage, the embryo is so far developed within the ovum that its head may be recognised by its possession of three pairs of horny hooklets. The ova require for further development that they should be introduced into the stomach of some animal, and this may be effected in one of two ways: (1) By some animal swallowing the microscopic ova along with its food or drink, or (2) by an animal actually eating one or more of the

detached proglottides, in which case decomposition of the proglottis and liberation of the contained eggs takes place in the gastric cavity of the new host.

When introduced by either of these methods into the stomach of a suitable animal, the horny capsule of the ovum undergoes solution, and the contained embryo or "proscolex" is liberated, in the form of a minute protoplasmic body provided anteriorly with three pairs of horny spines (fig. 146, *f*). Armed with these, the proscolex perforates the wall of the stomach of its host, and may either penetrate some contiguous organ, or may pierce a blood-vessel, in which case it may be carried by the current of blood to the liver, brain, eye, or some other organ of the body.

Having by one of these methods reached a suitable resting-place, the "proscolex" becomes encysted, and proceeds to develop a bladder-like vesicle, filled with a clear albuminous fluid, from its hinder extremity (fig. 146, *g*). The larval worm is now known as a "scolex," "*Cysticercus*," or "Cystic Worm," and it may be microscopic in its dimensions, or may reach a size of a quarter of an inch or more. When thus encysted within the tissues of an animal, the "scolex" consists of a tænioid head, with a crown of horny hooklets, and four "oscula" or suckers, united to the caudal bladder by means of a contracted, often transversely wrinkled, neck. In many cases the head and neck are not protruded from the caudal vesicle, but are entirely withdrawn, and are spirally coiled up within an inversion of the latter. The integument contains the so-called "calcareous corpuscles," which are seen in the adult tape-worm; but the scolex exhibits no traces of the reproductive organs, and is usually incapable of further development in its encysted condition. In some cases, however, the primitive scolex has the power of giving rise to secondary scolices by a process of gemmation, thus producing a compound bladder-like structure ("hydatid"), the dimensions of which may be very considerable.

As a general rule, the encysted scolex remains quiescent and unchanged, its life being of considerable duration, but terminating in ultimate degeneration, unless a fresh change of habitat be effected. If, however, the flesh of the "intermediate bearer" should be eaten by another suitable animal, and the encysted scolex be thus introduced into the alimentary canal of a "final host," a new series of changes is initiated. The scolex now attaches itself to the mucous membrane of the intestine of its new host by means of its cephalic hooklets (when these are present) and suckers. The caudal vesicle is

absorbed, and the scolex is thus converted into the "head" of the adult tape-worm. Gemmation then commences from its posterior extremity, the first segments being immature. As the first-formed joints, however, are pushed further from the head by the constant intercalation of fresh articulations, they become sexually mature, thus constituting the "proglottides" of the adult tape-worm with which the cycle began. To the entire organism, with its "head" and its mature and immature joints ("proglottides"), the term "strobila" is now applied.

In the case of all those tape-worms the life-history of which has been fully worked out, the general course of development is as above sketched out; though there are modifications of the process in different forms of the group. Of the various tape-worms (about eight in number) to which man is known to act as the "final host," several are exceedingly rare in their occurrence, while we are largely or wholly ignorant of their development. There are, however, three forms of tape-worms which commonly infest man in their adult condition, and the history of which may be briefly glanced at here. The first of these is the *Tænia solium* or "Pork tape-worm," which is found in the small intestine of man—sometimes solitarily, sometimes to the number of half a dozen or more—and which grows to a length of about ten or twelve feet. The Pork tape-worm is one of the "armed" tape-worms, its head having a crown of hooklets, in addition to its four suckers (fig. 147, B). When fully matured, the "strobila" consists of about eight hundred and fifty proglottides, of which the last hundred or fewer may be "ripe" or fully developed. The generative pores are lateral, placed usually on alternate sides of successive joints; and the uterus (fig. 147, A) is much less minutely branched than in the Beef tape-worm. The scolex of the *Tænia solium* is most generally found in the pig, commonly encysted in the muscles, and usually present in considerable numbers. It grows to a size of a quarter of an inch, and was originally described as a distinct worm, under the name of *Cysticercus cellulosæ* (fig. 146, *g*). Infection results from the eating by a human being of a portion of the flesh of a pig which is "measly," or, in other words, contains one or more of these *Cysticerci*. Though the *Cysticercus cellulosæ* is most usually found in the pig, both wild and domesticated, it also occurs encysted in the tissues of other animals, and not very uncommonly in man himself, the two commonest situations in which it has been detected in the human subject being the brain and eye. When encysted in the muscles, the *Cysticercus cellulosæ* does not necessarily give rise to any special symptoms unless present in great numbers; but the presence of even a single *Cysticercus* in such an organ as the brain may produce serious disease, or even death.

A commoner human parasite than the preceding is the Beef tape-worm (*Tænia mediocanellata* or *T. saginata*). This is one of the "unarmed" tape-worms, its head (fig. 146, *e*) having four suckers, but no hooklets; and it grows to a length of twenty feet or more, the strobila containing twelve hundred or more joints, of which the last two hundred may be "ripe." The mature joints are wider than in *T. solium*, with laterally and alternately placed genital pores, and having the uterus dendritically branched. The scolex (*Cysticercus bovis*) is found in the ox in all its varieties, its most general position being in the muscles, and its size being mostly under two-fifths of an inch.

The third human tape-worm which may be here alluded to is the "Broad tape-worm" (*Bothriocephalus latus*), sometimes called the "Rus-

sian tape-worm" from its common occurrence in Russia, though it also occurs in other countries as well (Poland, Switzerland, Ireland, &c.). This remarkable parasite is the largest of the human Cestodes, the strobila growing to the length of twenty-five feet, and being composed of over three thousand proglottides. The joints (fig. 147, F) are proportionately very narrow in their antero-posterior development, but are very wide; and the rosette-shaped uteri open by genital pores placed on the flat surface of each proglottis. The head (fig. 147, E) is "unarmed," oval in shape, and furnished with two long slit-like suckers. The proglottides are thrown off in groups, and the ova are enclosed in a horny capsule furnished with a lid at one end. The embryo is at first aquatic, swimming actively by means of a ciliated integument (fig. 147, D). The ciliated embryo gives rise to a minute "cystic" larva, which has an invaginated head, and lives encapsuled in the muscles of the pike and other fresh-water fishes.

Not only does man act as the "final host" to the three Cestodes mentioned above, as well as to several other forms of tape-worms, but he may also play the part of "intermediate bearer" in the case of other species. This is known to occur as regards *Tænia solium*; but it is of more common occurrence in the case of one of the tape-worms of the dog—viz., the *Tænia echinococcus*. The "strobila" of this species inhabits the intestine of the dog, and is composed of four segments only, counting in the "head" (fig. 148,

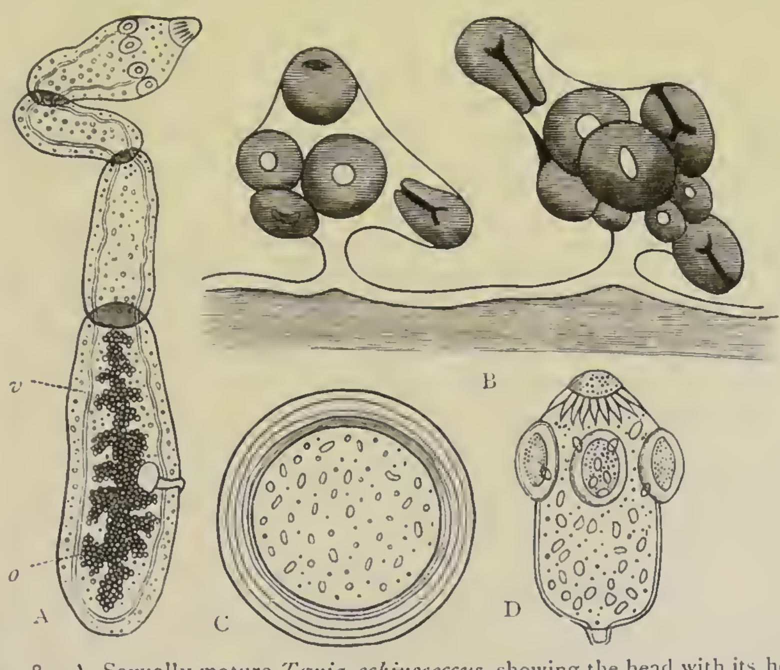

Fig. 148.—A, Sexually mature *Tænia echinococcus*, showing the head with its hooklets and suckers, and the three succeeding proglottides, the last containing the reproductive organs (enlarged): *o* Ovary; *v* Water-vessels. B, Interior of a portion of a hydatid cyst, showing the brood-capsules and included *Echinococci* (from Man). C, Young *Echinococcus*, about six weeks old, showing the thick laminated outer capsule and the inner granular contents. D, Single *Echinococcus* (from Man), showing the hooklets, suckers, contained "calcareous corpuscles," and pedicle. All the figures are enlarged. (After Spencer Cobbold and Wilson.)

A). The last segment only is sexually mature, and the head is furnished with hooks and suckers. The egg, when swallowed by man, gives origin to a "proscolex," which bores its way through the walls of the stomach,

and may either lodge in some neighbouring tissue, or, gaining access to a blood-vessel, may be carried to the liver, lungs, brain, kidneys, or other internal organ, the liver being most frequently affected. The proscolex encysts itself, and gives rise to a primitive scolex (fig. 148, C), in the form of a central granular mass enclosed in a thick laminated external envelope. The original scolex now begins to produce new scolices by a process of gemmation, the ultimate result being the formation in the organ affected of what is called a "hydatid tumour." Such a tumour consists ordinarily of a globular or lobulated cyst, varying in size from the dimensions of a nut up to that of an orange, one or more of these being lodged in some solid organ. The cyst is filled with a clear, transparent, straw-coloured fluid, remarkably free from albuminoids, but containing much chloride of sodium. It is formed (fig. 148, B) of an outer laminated elastic layer, and a much thinner internal, comparatively inelastic layer. The inner layer may be regarded as representing the combined caudal vesicles of a number of scolices, and is the essentially vital part of the structure. Little connection exists between the two layers, and if the cyst be laid open, and the contained fluid let out, the inner layer often collapses, and exhibits a characteristic "tremulous motion, at the same time coiling upon itself wherever there is a free cut margin" (Cobbold). The inner lining of the cyst produces by gemmation innumerable scolices, which have been described under the name of *Echinococcus hominis* or *E. veterinorum.* Each "Echinococcus" is from $\frac{1}{80}$ to $\frac{1}{100}$th of an inch in size, solid throughout, with four suckers and a crown of hooks (fig. 148, D). Many of the scolices become, however, ultimately transformed into delicate cysts or "brood-capsules," from which numerous secondary scolices are budded out (fig. 148, B); these becoming inverted and withdrawn into the brood-capsule, though some may be everted. Secondary brood-capsules may also be developed in the interior of the primary capsules.

Hydatid tumours are of not uncommon occurrence in countries in which drinking-water is taken from ponds or wells to which dogs have free access; and they commonly give rise, by pressure upon surrounding structures, to serious or even fatal disorders. Man is not the only animal liable to be infested by the scolices of the *Tænia echinococcus*,—oxen, sheep, and horses, in particular, being very subject to hydatids. The adult worm is only developed in case one of the "Echinococci" should be swallowed by a dog. It is from the horse, ox, or sheep, therefore, that the dog is liable to become infected with the adult worm; and it is chiefly in countries where dogs are commonly fed upon the offal of the slaughter-houses that the *Tænia echinococcus* is at all a frequent parasite in the dog.

As regards some other well-known tape-worms, the *Tænia marginata* of the dog spends its larval condition in the sheep and other Ruminants, as the *Cysticercus tenuicollis.* The *Tænia serrata* of the dog has for its scolex the *Cysticercus pisiformis* of hares and rabbits. The larva of the *Tænia cucumerina* of the dog—a Cestode which also occurs in its adult condition in the human subject—inhabits the common louse of the dog (*Trichodectes latus*); and the dog becomes infected by licking itself, and thus swallowing the louse. Still another tape-worm of the dog—viz., the *Tænia cœnurus*, inhabits in its larval state the sheep, the scolex in this case having the power of internal multiplication or budding, and thus producing "hydatid tumours." The hydatid cysts of *Tænia cœnurus* (originally described as *Cœnurus cerebralis*) are found in the brain of the sheep, goat, and other animals, and they give rise in the former of these to the disease known as "staggers" or "sturdy." The *Tænia crassicollis* of the cat is the mature form of the *Cysticercus fasciolaris* of the mouse; and the *Tænia crassiceps* of the fox is derived from the *Cysticercus longicollis* of the Vole (*Arvicola terrestris*).

CHAPTER XXII.

TREMATODA AND TURBELLARIA.

ORDER TREMATODA. — *Leaf-like, rarely vermiform, internal (sometimes external) parasites, provided with one or more ventral suckers; a mouth and alimentary canal, but no anus. No body-cavity. Integument of the adult not ciliated. Sexes generally united.* This order includes a group of animals, which, like the preceding, are parasitic, and are commonly known as "Suctorial Worms" or "Flukes." They inhabit various situations in different animals—mostly in birds and fishes—and they are usually flattened or roundish in shape. The body is provided with one, two, or more suctorial discs, by means of which the animal adheres to its host. The alimentary canal is simply hollowed out of the parenchyma of the body, and does not lie in a free space or "perivisceral cavity." The intestinal canal is always bifurcated behind the gullet, and its two divisions may either remain simple (as in *Distoma lanceolatum*, fig. 149, *i i*), or may be more or less branched (as in *Distoma hepaticum*, fig. 150). In any case, the divisions of the alimentary canal terminate blindly behind. The opening of the mouth is always placed at the front end of the body, and is usually situated at the bottom of an anterior sucker (fig. 149, *aa*). A "water-vascular" system is present, and consists of two principal lateral vessels, which are connected with minute branching tubes, and open posteriorly into a common contractile vesicle, which communicates with the exterior by an excretory pore (fig. 149, *p*). The nervous system consists of a double ganglion placed above the gullet.

With few exceptions, the sexes are united in the same individual, and the reproductive organs are of a very complicated description. The generative apertures are placed close together, anteriorly and on the ventral side (between the two suckers in *Distoma*, fig. 149, *c*). The male organs consist of testes, with *vasa deferentia*, and of a dilated sac containing a protrusible penis. The female organs consist of an ovary and oviduct, a much-branched uterus (fig. 149, *u*), and of two large "vitelligenous glands." Development is in some cases simple; but there is generally a metamorphosis, accompanied by an "alternation of generations."

The "Fluke-worms" inhabit, in their adult condition, the most varied situations. Most are internal parasites, living in the intestines or hepatic ducts of Mammals, Birds, or Batrachi-

ans, the vitreous humour or lens of the eye, the blood-vessels, &c. A few are external parasites, living on the skin and gills of fishes, Crustaceans, and other animals.

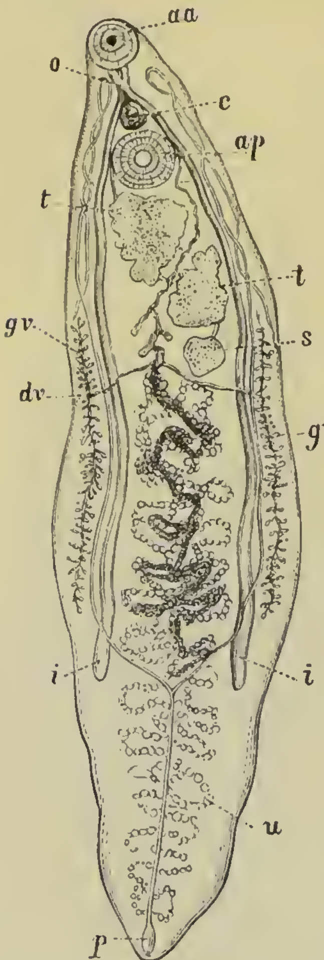

Fig. 149.—A Trematode Worm (*Distoma lanceolatum*), enlarged. *aa* Anterior sucker, with the mouth at its bottom; *ap* Posterior sucker; *o* Gullet, dividing behind into the two branches of the intestine, which are unbranched, and terminate behind in blind extremities (*i i*); *p* External opening of the water-vessels, which divide above so as to cross the blind ends of the intestine; *t t* Testes; *c* Openings of reproductive organs; *gv* Vitelligenous glands; *dv* Oviducts; *u* Uterus.

As the type of the Trematodes the common Liver-fluke (*Distoma hepaticum*) may be selected. This well-known parasite inhabits in its adult state the biliary ducts of the sheep, ox, horse, hare, &c., or of man himself; but its natural host appears to be the sheep, in which animal it causes by its presence the widely-spread and commonly fatal disease known as the "rot." The adult *Distoma hepaticum* (fig. 150, A) is ovate and leaf-like in form, usually from a quarter of an inch to an inch or more in length, the cuticle being covered with minute horny spines. Below the true skin is a layer of longitudinal and transverse muscular fibres, and the general parenchyma of the body is composed of polygonal cells. Two suckers are present, one placed anteriorly and perforated by the opening of the mouth, the other situated posteriorly on the ventral surface and imperforate. Between the two are the closely apposed generative apertures. Both of the suckers are used in locomotion, and the ventral sucker is the principal organ of adhesion. The mouth opens into a short gullet, which divides into two principal intestinal tubes, which in turn give off numerous branched cæca. The contents of the intestine are mostly bile derived from the bile-ducts of the host, and the branched alimentary canal is thus dark in colour. There is no anus, nor perivisceral cavity, and the digestive canal is simply excavated out of the general tissues of the body. There is a branched system of water-vessels, which open posteriorly by a caudal pore, and contain a watery fluid in which float refracting corpuscles. The reproductive organs of the two sexes are present in the same individual, and are extremely complicated.

The following are the principal phenomena in the life-history of the Liver-fluke, as worked out by Mr A. P. Thomas. The ova of *Distoma hepaticum* are exceedingly numerous, a single individual often containing many thousands; each being oval in shape, with a chitinous covering and a distinct lid (fig. 150, B), the long diameter being about $\frac{1}{200}$th of an inch. The ova pass from the bile-ducts of the sheep into the intestine, but are unable to develop themselves within the body of the sheep, and are therefore expelled along with the fæces. Should the ova reach water, they hatch,

and give origin to minute embryos, each of which is an inversely-conical ciliated body (fig. 150, C), with a double pigment-spot or "ocellus," and a short proboscis in front. The embryo swims actively in the water by means of its cilia; but its independent life only lasts a few hours, and it perishes unless it should meet with its proper host.

This host is one of our common Water-snails—viz., the *Limnæa truncatula*—a Mollusc which is amphibious in its habits, and is found just as often out of the water as in it. Should the ciliated embryo of *Distoma hepaticum*

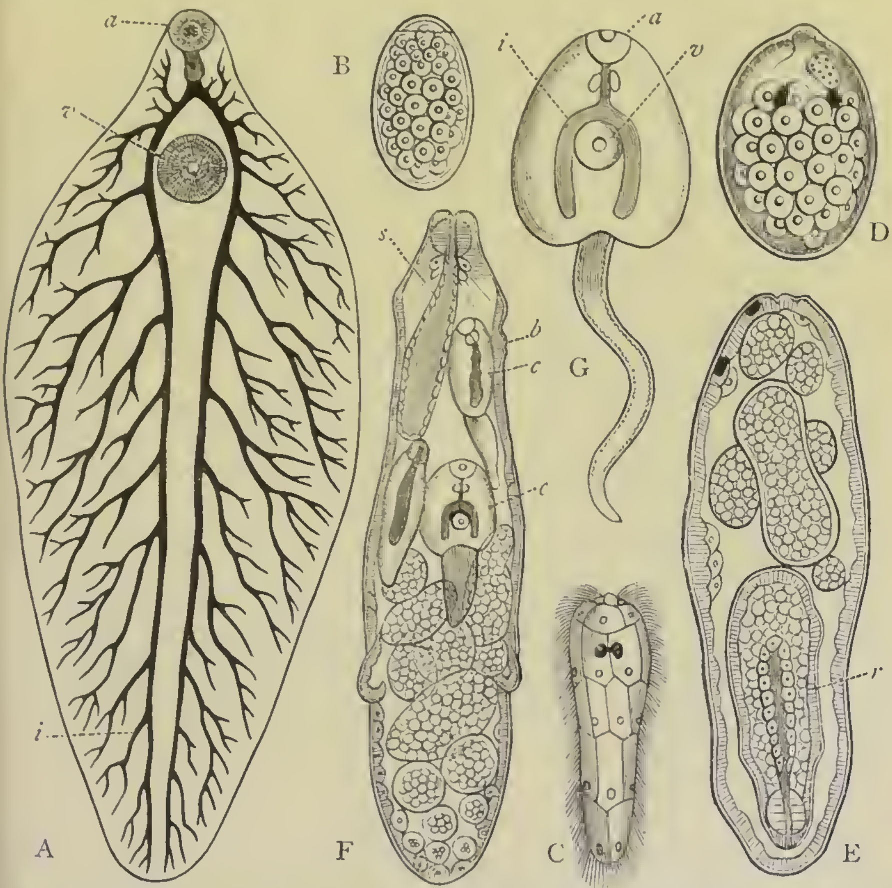

Fig. 150.—*Distoma* (*Fasciola*) *hepaticum*. A, The adult worm, viewed from the ventral surface and enlarged, showing the branched alimentary canal; B, Ovum, with its lid; C, Ciliated free-swimming embryo, with its proboscis and eye-spots; D, A young "sporocyst"; E, An adult "sporocyst," with a nearly mature "redia" (*r*) in its interior; F, An adult "redia," containing two "cercariæ" (*c c*), a daughter-redia, and numerous germs; G, Free "cercaria." *a* Anterior sucker; *v* Ventral sucker; *i* Intestine; *s* Digestive sac of "redia"; *b* "Birth-opening" of "redia." Figs. B—G are enlarged, and are after A. P. Thomas.

meet with one of these snails, it bores into its tissues by means of its proboscis, and lodges itself in the pulmonary chamber or body-cavity of the Mollusc. When it has attained this position, the embryo loses its cilia, and becomes sac-like, its contents at the same time breaking up into cells, when it constitutes what is known as a "sporocyst" (fig. 150, D). The "sporocyst" may be regarded as a kind of brood-sac for the second generation of

larval forms, and its cells (fig. 150, E) ultimately arrange themselves so as to form one or more secondary embryos, which are called "rediæ," after the Italian naturalist Redi.

When fully mature, the "redia" breaks through the wall of the "sporocyst" in which it was produced, and bores its way into the tissues of the snail, finally lodging in some solid organ, generally the liver. The "redia" (fig. 150, F) now increases in size, and may grow to $\frac{1}{20}$th of an inch in length. It has a mouth, muscular pharynx, and sac-like stomach; and its contents break up into a number of tertiary germs. Some of these internal germs become "daughter-rediæ"; but others become developed into tadpole-like embryos, which are termed "cercariæ."

Both the "daughter-rediæ" and the "cercariæ" are liberated from the original redia by means of an opening in the walls of the latter, known as the "birth-opening" (fig. 150, F, *b*). The "cercaria" thus set free consists of an oval body, furnished with a long swimming-tail (fig. 150, G), and having an anterior and posterior sucker. At the bottom of the anterior sucker is placed the mouth, which leads into a gullet, which divides into two simple branches. The condition of the intestine of the "cercaria" is, therefore, similar to what it is in such adult Flukes as *Distoma lanceolatum*. The "cercaria" works its way out of the snail by means of its suckers and tail, and thus gains access to water, in which it swims actively.

After a brief free life, the cercaria attaches itself by means of its suckers to some foreign body, such as a blade of grass, when it loses its tail, and becomes surrounded by a white horny cyst. Should one of these "encysted" cercariæ be swallowed by a sheep along with its food, the horny envelope of the larva is dissolved, and the young Fluke thus set free makes its way into the bile-ducts, where it obtains its reproductive organs, and assumes its final characters.

Besides the common Liver-fluke, other species of Distoma (*D. crassum* and *D. lanceolatum*, fig. 149) have been recognised as occurring in man. In *D. lanceolatum* the intestine is simply forked, instead of being branched. It occurs in the liver of the ox, sheep, pig, &c. Another Trematode which is a human parasite is the singular *Gynæcophorus* (*Bilharzia*) *hæmatobius*, which inhabits the interior of certain of the blood-vessels of the human subject in particular regions (Egypt, South Africa, Mauritius). The sexes are distinct in this form, both being vermiform in shape, and the female being lodged in a groove on the ventral surface of the male.

ORDER TURBELLARIA.—*Leaf-like or vermiform, non-parasitic Scolecids, with a mouth and alimentary canal, and sometimes a body-cavity; integument ciliated. Sexes united or distinct.* The members of this order are almost all aquatic, and are all non-parasitic; thus differing entirely from the animals which compose the two preceding orders. Their external surface is always and permanently ciliated, and they never possess either suctorial discs or a circlet of cephalic hooklets. A "water-vascular system" is present, opening externally by one or more apertures, or appearing to be entirely closed in the adult (*Nemertida*). The alimentary canal is embedded in the parenchyma of the body (*Planarida*), or is freely suspended in a "perivisceral cavity" (*Nemertida*). The intestine is either straight or branched, and a distinct anal aperture may, or may not,

be present. The nervous system consists of a pair of supra-œsophageal ganglia, which send lateral nerves backwards.

The *Turbellaria* are divided into two sections, termed respectively the *Planarida* and the *Nemertida*.

SUB-ORDER I. PLANARIDA.—The Planarians (fig. 151) are mostly ovoid or elliptical in shape, flattened and soft-bodied. They are for the most part aquatic in their habits, occurring in fresh water, or on the sea-shore, but occasionally found in moist earth. The integument is abundantly provided with vibratile cilia, which subserve locomotion, and it also contains numerous cells, which are in many respects very similar to the "cnidæ," or nettle-cells, of the *Cœlenterata*. There is always a considerable portion of the body situated in front of the mouth, constituting the so-called "præ-oral region," or "prostomium"; and this is often modified into a singular protrusible and retractile organ called the "proboscis." The mouth opens into a muscular pharynx, which is often evertible; and the intestine may be either straight or branched, but always terminates cæcally behind, and is never provided with an anal aperture. The "water-vascular system" communicates with the exterior by two or more contractile apertures. The Land-Planarians (*Geoplanidæ*) have the ordinary branched water-vascular system replaced by two nearly simple canals, which are occupied by spongy tissue, and

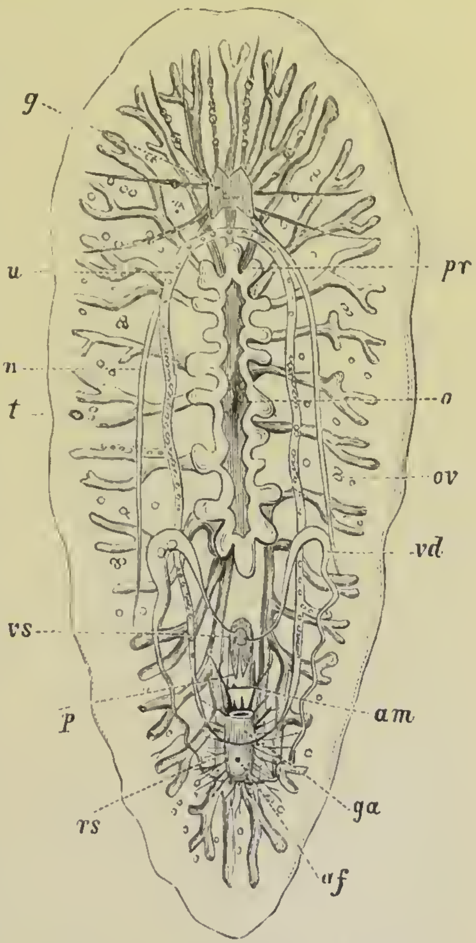

Fig. 151.—One of the Planarian Worms (*Leptoplana tremellaris*), enlarged. *o* Mouth; *pr* Proboscis; *g* The principal nerve-ganglion, placed in the anterior part of the body, and giving off numerous radiating branches (*n*); *p* Penis; *vd*, Vas deferens; *vs* Vesicula seminalis; *am* Opening of male reproductive organs; *t* Testis; *ov* Ovary; *u* Uterus, partly filled with eggs; *af* Opening of the female reproductive organs; *rs* Receptaculum seminis; *ga* Albuminiparous gland.

are not certainly known to communicate with the exterior. The nervous system consists of two ganglia, situated in front of the mouth, united by a commissure, and giving off filaments in various directions. Pigment-spots, or rudimentary eyes, from two to sixteen in number, are often present, and are always placed in the præ-oral region of the body. The male and female organs are united in the same individual, and the process of reproduction may be either sexual, by means of true ova, or non-sexual, by internal gemmation or transverse fission. Development may be direct, or there may be a marked metamorphosis.

The *Planarians* have been divided into two sections, as follows:—

Section A. RHABDOCŒLA.—Intestine straight, not branched; body elongated, rounded, or oval.

Section B. DENDROCŒLA.—Intestine branched or arborescent; body flat and broad.

SUB-ORDER II. NEMERTIDA.—The *Nemertida*, or "Ribbon-worms," agree in most essential respects with the *Planarida*. They are distinguished, however, by their elongated, vermiform shape, by the presence of a distinct anus, by the possession of a distinct perivisceral cavity, by the presence of a closed system of "pseudohæmal" vessels, and by the fact that the sexes are generally distinct. The external surface of the body is richly ciliated, and is underlaid by a thick glandular cutis, beneath which are well-developed subcutaneous muscles. The digestive canal is ciliated internally, and consists of a muscular gullet, a sacculated stomach, and an intestine with a distinct anus. In *Pelagonemertes* (fig. 153) the alimentary canal is branched, as in many Planarians. The nervous system consists of two large cephalic ganglia, united by a double commissure, and sending lateral cords backwards. The so-called "circulatory system" ("pseudohæmal" system) is composed of closed contractile vessels, sometimes containing a corpusculated fluid. In a few forms (as in *Tetrastemma*) there may be water-vessels in addition to the pseudohæmal vessels. "Along the median line of the dorsum lies a special muscular sheath, containing a complicated proboscis, and a highly organised corpuscular fluid, both the sheath and the proboscis passing between the commissures of the ganglia in front" (M'Intosh). The evertible and muscular sheath of the proboscis may be as long as the whole body, and the extremity of the latter may or may not be protected by one or more spines (fig. 152). The sexes are mostly in separate individuals, and the generative organs have the form of sacs placed between

the muscular walls of the body and the digestive canal, and discharging their contents by lateral pores.

As regards the development of the Nemerteans, there may or may not be a metamorphosis. In some forms, the egg gives rise to a helmet-shaped ciliated provisional larva, which was originally described under the name

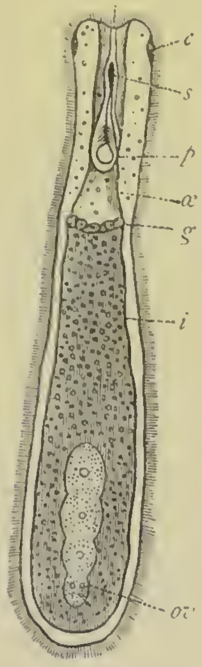

Fig. 152.—Morphology of *Nemertida*. *Prorhynchus fluviatilis*: *o* Mouth; *c* Ciliated grooves (sense-organs?); *s* Spine, attached behind to (*p*) the sac of the proboscis; *æ* Gullet; *g* Gastric glands; *i* Intestine; *ov* Ovary. The proboscis in this form is very small. (After Gegenbaur.)

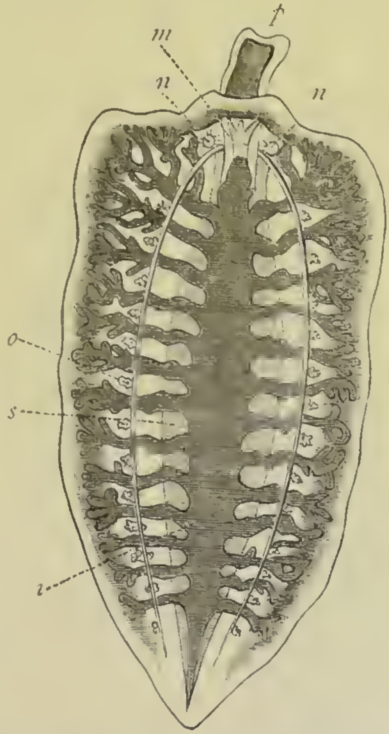

Fig. 153.—Nemertida. *Pelagonemertes Rollestoni*, a pelagic Nemertid, viewed from the ventral surface. *p* Proboscis, partially protruded; *m* Opening of the mouth; *i* Alimentary canal, with its lateral diverticula, shaded darkly; *s* The sheath of the proboscis, more lightly shaded; *n n* The nerve-ganglia, placed one on each side of the mouth, and each giving off a long lateral and backwardly-directed branch, external to which, on each side, is a row of ovaries (*o*). (After Moseley.)

of *Pilidium*, and which is in many respects similar to the ciliated pseudembryo of the Echinoderms. The young Nemertine is ultimately produced in the interior of the *Pilidium*, by the formation of a mass of formative matter which grows round and appropriates the alimentary canal of the larva, and finally breaks through the ciliated skin of the latter.

The Nemerteans are mostly marine in their distribution, a few forms inhabiting fresh water, and two (the *Tetrastemmæ* of the Bermudas and Philippine Islands) being found in moist places on land. They are found from the Arctic seas to the

equator, most of them being littoral in their habits, though some live at considerable depths. Some forms (like the leech-like *Malacobdella*) are parasitic on Crustaceans or Molluscs. Recently, Professor Moseley has described a peculiar group of Nemerteans under the name of *Pelagonemertidæ*, which are pelagic in their habits. These oceanic forms (fig. 153) have a broad, gelatinous, flattened body, and a ramified digestive tract, and thus make a near approach to the dendrocœlous Planarians. No certain remains of Nemertids are known to occur in the fossil state, though some obscure remains have been referred to this group.

ENTEROPNEUSTA.—Allied on the one hand to the Echinoderms, and on the other hand to the Worms, is the singular genus *Balanoglossus*, for which the group of the *Enteropneusta* has been founded. The species of *Balanoglossus* burrow in the sand of the sea-bottom, extending their range to 2500 fathoms in depth. The body in this genus is worm-like, and terminates anteriorly in a muscular collar, in front of which is a large protrusible hollow proboscis. The external integument is ciliated, as in the Nemerteans, and there are no setiform organs of locomotion, such as are found in so many Annelides. The mouth opens ventrally at the point where the collar and proboscis join, and leads into a pharynx, the upper part of which is specially modified to serve as a respiratory organ. This portion of the pharynx has its walls supported by a chitinous framework, with intervening ciliated apertures, from which the water taken in at the mouth passes out into a series of chambers, which in turn communicate with the exterior by a row of dorso-lateral slits on each side. A pseudohæmal system of vessels is present, and the sexes are in different individuals. The larva of *Balanoglossus* in many respects resembles the pseudembryo of some of the Echinoderms, and was originally described by Müller as the young of a Star-fish, under the name of *Tornaria*. The larva is, however, developed into the adult by a rapid change, not accompanied by any absorption, or casting off, of any portion of the former. As regards its respiratory organs, *Balanoglossus* shows some interesting resemblances to the Tunicates; and Bateson has shown that it has also some points of relationship with the Lancelet (*Amphioxus*).

CHAPTER XXIII.

NEMATELMIA.

1. ACANTHOCEPHALA. 2. GORDIACEA. 3. NEMATODA.

DIVISION II. NEMATELMIA.—This section may be considered as comprising those Scolecids in which the body has an elongated and cylindrical shape. Most of the *Nematelmia* possess

an annulated integument; but there is no true segmentation, and there are rarely any locomotive appendages attached to the body. The majority are unisexual, and parasitic during the whole or a part of their existence. Three orders are comprised in this division—viz., the *Acanthocephala*, the *Gordiacea*, and the *Nematoda*.

ORDER I. ACANTHOCEPHALA.—*Vermiform internal parasites, without mouth or alimentary canal, and having an anterior protrusible proboscis armed with recurved hooks. Sexes distinct.*

The *Acanthocephala* are entirely parasitic, vermiform in shape, and devoid of any mouth or alimentary canal. The front end of the body (figs. 154 and 155) is developed into a retractile proboscis, which is covered with transverse rows of recurved hooks, and by means of which the parasite attaches itself to the wall of the intestine of its host. The integument (c c) is highly muscular, and the proboscis is contained within a strong muscular sheath, and can be retracted by special muscular bands (m m). At the base of the proboscis is placed a single nervous ganglion, and its hinder extremity is prolonged into l, the so-called "ligamentum suspensorium," a fibrous band, which supports the generative organs. The sexes are in different individuals. The water-vascular (?) system is in the form of subcutaneous reticulated canals which are connected with two saccular organs or "lemnisci" (b b), placed on each side of the base of the proboscis, but the vessels of this system do not appear to communicate with the exterior. The reticulated dermal canals are sometimes regarded as being nutritive in function, while the lemnisci have been looked upon as excretory organs.

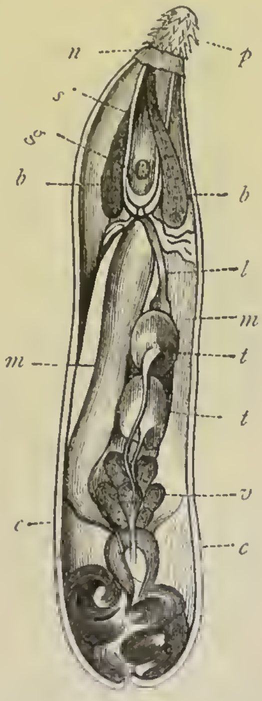

Fig. 154.—Morphology of *Acanthocephala*. Male of *Echinorhynchus angustatus*, enlarged about twelve times: p Proboscis; n Neck; s Muscular sheath of the proboscis; g Ganglion; b b "Lemnisci," or sacs connected with the water-vascular system; l Ligamentum suspensorium; m m Retractor muscles of the proboscis; t t Testes; v Vesicula seminalis; c c Integument. (After Leuckart.)

The order *Acanthocephala* includes only one genus, namely, *Echinorhynchus*, the genus *Koleops* being doubtfully referred here. All the *Echinorhynchi* inhabit in their adult condition the in-

testines of fishes, birds, or Mammals, and they pass through a metamorphosis. The eggs are swallowed by Crustaceans or insects, and give exit to free vermiform embryos, armed with hooks. These burrow out of the intestine of their host and encyst themselves in its tissues, not becoming finally developed till their bearers may be eaten by some vertebrate animal. Thus, the embryos of *Echinorhynchus gigas* of the pig inhabit the larvæ of the cockchafer; whilst those of *E. angustatus*, of Cyprinoid fishes, live in the interior of fresh-water Crustaceans.

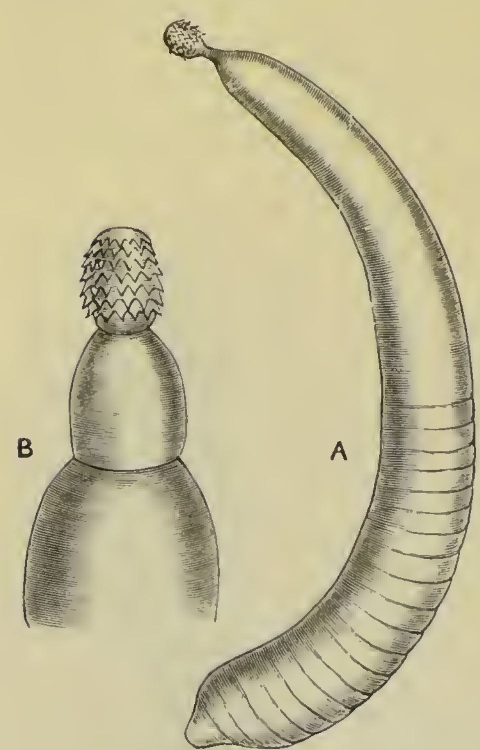

Fig. 155.—Acanthocephala. A, *Echinorhynchus gigas*, slightly enlarged; B, Head of the same, still further enlarged.

ORDER II. GORDIACEA.—*Vermiform Scolecida, parasitic in insects during a portion of their existence. An imperfectly developed alimentary canal, or none. Water-vascular system rudimentary or absent. Sexes distinct.*

The *Gordiacea*, or "Hair-worms," are thread-like Scolecids, often singularly like hairs in appearance (fig. 156), which live in the interior of various insects during part of their life. The digestive system is imperfect, an anal aperture being universally wanting. In *Mermis*, the gullet ends in a blind sac; in *Gordius*, the digestive tube opens into the body-cavity; and in *Sphærularia*, the mouth appears to be wanting. The sexes are in different individuals. In *Gordius* itself, the embryo (fig. 156, B) is free and aquatic, having a retractile snout armed with hooklets, by means of which it, after a time, bores its way into the tissues of some water-insect, in which it encysts itself. The sexually-mature worms are found in the interior of *Orthoptera* or *Neuroptera*; but they leave their hosts and betake themselves again to an aquatic existence for the purpose of laying their eggs. The adult *Mermis* is found principally in *Lepidoptera*; whilst *Sphærularia* inhabits the body-cavity of

Bumble-bees. A form of the *Gordiacea* has also been found at great depths in the ocean, coiled up beneath the carapace of shrimps (Willemöes-Suhm).

The common Hair-worm (*Gordius aquaticus*, fig. 156), is found in ponds and rivers in Europe and North America, and may be two or three feet long when fully mature. It sometimes occurs in great numbers, inextricably coiled together, and may be found in moist earth as well as in water. The adult worm is also found coiled up round the intestine of Ground-beetles or Grasshoppers. The eggs are white, and are deposited in long chains in water. The embryo is at first free and locomotive, with three pairs of cephalic hooklets, a well-developed alimentary canal, and a protrusible proboscis. The larva, thus armed, makes its way into the larvæ of water-insects, in which it encysts itself. Should the insect-larvæ thus infested be eaten by a fish, the young Hair-worm bores into the intestinal wall of the latter, and again encysts itself. After a prolonged period of rest, the *Gordius* larva bores out of its cyst into the intestine of the fish, and escapes with the fæces into the surrounding water, when it becomes converted into the adult worm.

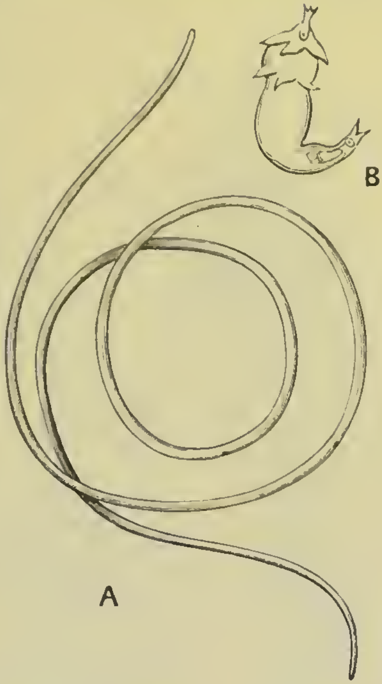

Fig. 156.—Gordiacea. A, A small individual of *Gordius aquaticus*, of the natural size. B, Larva of *Gordius subfurcatus*, with its piercing proboscis and two rows of hooks, enlarged.

ORDER III. NEMATODA (or *Nematoidea*).—*Cylindrical vermiform Scolecids, sometimes parasitic, sometimes free; integument not ciliated; a well-developed alimentary canal, with a mouth and anus, suspended freely in a body-cavity; sexes distinct, or rarely united.*

The *Nematoda* comprise the so-called "Thread-worms" and "Round-worms," and, as their various names imply, possess a rounded and worm-shaped body (fig. 157), sometimes of great length. The cuticle is chitinous and porous; and there is generally a distinct annulation, though no true segmentation exists. The alimentary system is well developed, the mouth being anterior, and usually furnished with papillæ (fig. 158, *c*). The gullet opens into a muscular cavity (the so-called gizzard or "pharynx"), from which an intestine conducts to a ventrally or terminally placed anus; the whole digestive tube being freely suspended in a body-cavity, which is filled with a sparsely corpusculated fluid. There is a water-vascular

system, composed of two lateral tubes, which open on the surface by a ventrally-placed pore. The nervous system is in the form of a ganglionic ring, surrounding the gullet, and sending filaments backwards and forwards. The sexes are mostly distinct, the external openings of the reproductive organs being placed near the anus in the males, but usually towards the centre of the ventral surface in the females. The males are usually less frequently met with and of smaller size than the females, and they possess a single or double spicular penis (fig. 158, *b*). Metamorphosis may or may not occur during development.

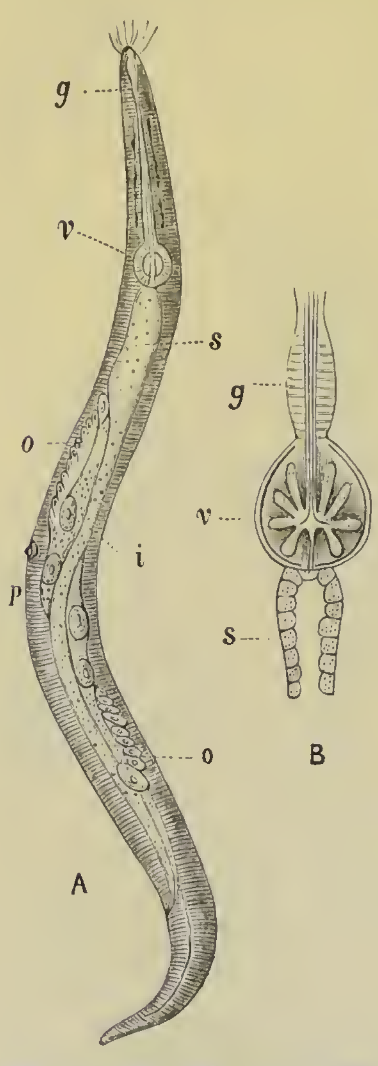

Fig. 157.—Nematoda. A, *Rhabditis bioculata*, female, enlarged. B, Portion of the alimentary tract of *Oxyuris vermicularis*, enlarged. *g* Gullet; *v* Muscular gizzard (or pharynx); *s* Chylific stomach, or anterior end of the intestine (*i*); *o o* Ovaries; *p* Genital pore.

As before said, most of the *Nematoda* are internal parasites, inhabiting the alimentary canal, the pulmonary tubes, the blood, or the areolar tissue, in man and in many other vertebrate animals; but a large section of the order are of a permanently free habit of existence.

Amongst the more important members of the parasitic section of the *Nematoda* may be mentioned the *Ascaris lumbricoides*, the *Oxyuris vermicularis*, the *Trichocephalus dispar*, the *Sclerostoma duodenale*, the *Dracunculus medinensis*, and the *Trichina spiralis*.

The *Ascaris lumbricoides*, or Common Round-worm, inhabits the intestine of man, and sometimes of other Mammals, especially the pig, often attaining a length of several inches. The ova are expelled with the fæces, and the embryo is developed within the ovum prior to its rupture, but not till after the lapse of several months (fig. 158, *d*). When fully formed, the embryo is about one-hundredth of an inch in length, and its development is not exactly known, though it appears to be directly transferred from river or pond water to the alimentary canal of its host. The body of the adult (fig. 158, *a*) is cylindrical, attenuated at both extremities. At the anterior extremity is a subtriangular mouth, surrounded by three tubercles (fig.

158, *c*). The anus is situated posteriorly. The females are larger than the males, and are much more numerous. These parasites are much more common in children than in adults, and they often occur in considerable numbers. They are usually found in the small intestine, though they sometimes wander into other situations.

The *Oxyuris vermicularis*, or "Small Thread-worm" (fig. 158, *e*, *f*, *g*),

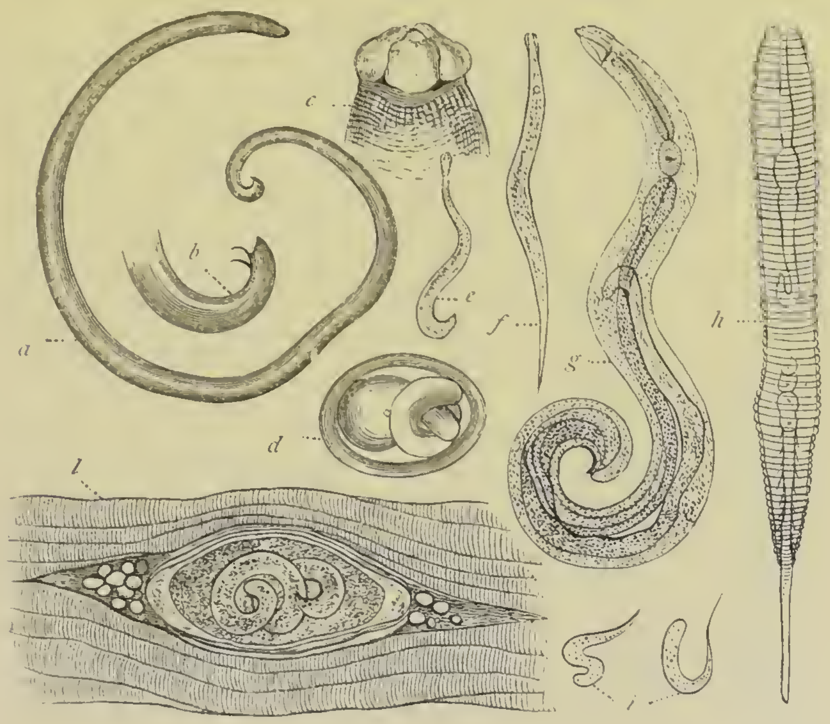

Fig. 158.—Morphology of Nematoda. *a Ascaris lumbricoides*, male, reduced in size; *b* Hinder extremity of the same, with the spicular penis, enlarged; *c* Head of the same enlarged, showing the tubercles round the mouth; *d* Ovum of the same, highly magnified, with the fully-developed worm in its interior; *e* Male of *Oxyuris vermicularis*, five times the natural size; *f* Female of the same, similarly enlarged; *g* Male of the same, highly magnified; *h* Embryo of *Dracunculus*, magnified 500 diameters; *i* Embryos of the same, magnified 60 diameters; *l* A single *Trichina*, encapsuled in the muscles, highly magnified. (Chiefly after Leuckart, Spencer Cobbold, and Bastian.)

is a gregarious worm, which inhabits the rectum, especially of children. It is the smallest of the intestinal worms of man, its average length not being more than a quarter of an inch, but the females are much bigger than the males.

The *Trichocephalus dispar* inhabits the cæcum of man. It is from one and a half to two inches in length, and the anterior two-thirds of the body is extremely attenuated and thread-like.

The *Dochmius* (*Sclerostoma*) *duodenale* inhabits the small intestine in the human subject, and is far from uncommon in Italy and in Egypt. It varies in length from one-third of an inch to half an inch, the females being the largest; and the symptoms to which it gives rise are often of a serious character.

The *Trichina spiralis* is a singular Nematoid, which gives rise to a painful and not uncommonly fatal train of symptoms, somewhat resembling rheumatic fever. The *Trichina* is known in two different conditions, sexually immature or mature. In its sexually immature condition it inhabits the muscles, usually of the pig (the rat, however, being apparently its true host), in vast numbers, each worm (fig. 158, *l*) being coiled up in a little capsule or cyst. In this condition the worm is incapable of further development, and may remain for a long period without change, and without seeming to produce any injurious results to the animal affected. In course of time the muscle-*Trichina* appears to degenerate and die, owing to the ultimate calcification of the wall of the enveloping cyst. If, however, a portion of trichinatous muscle be eaten by a warm-blooded Vertebrate, and so introduced into the alimentary canal, an immediate development of young *Trichinæ* is the result. The immature worms escape from their enveloping cysts, grow larger, develop sexual organs, and give birth to a numerous progeny, which they produce viviparously. The young *Trichinæ* thus produced perforate the walls of the alimentary canal, and, after working their way amongst the muscles, become encysted. If the animal in which these changes go on has sufficient vitality to bear up under the severe symptoms which are produced by the migration of the *Trichinæ*, he is now safe; since they cannot become sexually mature, or develop themselves further, until again transferred to the alimentary canal of some other animal. The female *Trichina* is about $\frac{6}{100}$ of an inch in length, and the male about half as long.

Fig. 159.—Free Nematoids. A, *Anguillula aceti*; B, *Dorylaimus stagnalis*. Magnified. (After Bastian.)

The Guinea-worm (*Dracunculus* or *Filaria medinensis*) is a Nematode worm, which inhabits, during one stage of its existence, the cellular tissue of the human body, generally attacking the legs, and often attaining a length of several feet. All known specimens of this parasite are impregnated females, containing a large number of young. The worm remains embedded in the body, in a more or less quiescent condition, for a year, less or more, at the end of which time it seeks the surface, in order to get rid of its young. No external aperture to the genital organs has hitherto been proved to exist, and it seems possible that the young are produced within the body of the parent by a process of internal gemmation. The young *Filaria* (fig. 158, *h* and *i*) consists of a vermiform body, terminating in a hair-like tail; and when set free from the parent, its further development probably takes place in water, when it has been shown to pass into the body of fresh-water Crustaceans (*Cyclops*). Whether it is swallowed in this condition by man, in drinking water; or whether it has a free stage, in which sexual organs are developed and impregnation of the females effected, is still an open question. The Guinea-worm is only known to occur within

the intertropical regions of both the Old and New World, and is especially abundant in Africa, Persia, and India.

In addition to the above-mentioned forms, it may be noted that minute parasitic Nematoids are not uncommonly found, sometimes in vast numbers, in the blood of various animals, including the dog, man himself, and various birds. Some of these hæmatozoa are embryonic, others appear to be mature, and they may or may not give rise by their presence to appreciable morbid symptoms. The origin of these hæmatozoa, their development, and the mode in which they are introduced into the blood, are subjects, for the most part, still shrouded in obscurity. The most remarkable species is the *Filaria sanguinis-hominis*, which in its immature state inhabits the blood of man in intertropical regions, its presence being commonly associated with chyluria, hæmaturia, and other morbid affections.

The second section of the *Nematoda* comprises worms which are not at any time parasitic, but which are permanently free. The typical group of the "Free Nematoids" is that of the *Anguillulidæ*, of which about two hundred species have been already described, mostly inhabiting fresh water or the sea. They resemble the parasitic Nematoids in all the essential features of their anatomy, but they differ in often possessing pigment-spots, or rudimentary eyes, in being mostly provided with a terminal sucker, and in bringing forth comparatively few ova at a time; the dangers to which the young are exposed being much less than in the parasitic forms. Amongst the more familiar free Nematoids are the Vinegar Eel (*Anguillula aceti*, fig. 159, A) and the *Tylenchus* (or *Vibrio*) *tritici*, which produces a sort of excrescence or gall upon the ear of wheat, causing the disease known to farmers as the "Purples," or "Ear Cockle."

The parasitic and free Nematoids are connected together by *Rhabdonema* (*Ascaris*) *nigrovenosum*, which in succeeding generations is alternately free and parasitic. This *Ascaris* has long been known as inhabiting the lungs of the frog, but it has been shown by Mecznikow that "the young of this animal become real free Nematoids; for, after passing from the intestine of the frog into damp earth or mud, they grow rapidly, and actually develop in the course of a few days, whilst still in this external medium, into sexually mature animals. Young, differing somewhat in external characters from their parents, are soon produced by them, and these attain merely a certain stage of development whilst in the moist earth, arriving at sexual maturity only after they have become parasites, and are ensconced in the lung of the frog" (Bastian). The individuals which are found in the lung of the frog are not of two sexes, but are all structurally females. They have the power, however, of producing spermatozoa in the ovaries.

Perhaps in the neighbourhood of the free Nematoids may be placed the aberrant genus *Chætosoma*, in which there is a double row of ventral bristles posteriorly, while the anterior extremity is swollen and also furnished with bristles. *Chætosoma* is found in the sea, and leads a free life.

CHAPTER XXIV.

ROTIFERA.

SUB-CLASS ROTIFERA (*Rotatoria*).—The *Rotifera*, or "Wheel-Animalcules," constitute a peculiar group of organisms, which

may be regarded as forming a special division of the Scolecids, though there is nothing worm-like about their general appearance.

The *Rotifera* are *minute animals, rarely parasitic, inhabiting water, and usually provided with an anterior ciliated disc, capable of inversion and eversion. In the females there is a distinct mouth, alimentary canal, and anus. A nervous system is also present, consisting of ganglia situated near the anterior extremity of the body, and sending filaments backwards. A water-vascular system is also present. The sexes are distinct.*

Most of the *Rotifera* are almost or quite invisible to the naked eye, and they are all extremely minute, none of them attaining a greater length than $\frac{1}{36}$th of an inch. They are all aquatic in their habits, and in the great majority of cases are free-swimming animals, some, however, being permanently fixed, as is the case with *Stephanoceros*, *Melicerta* (fig. 160, B),

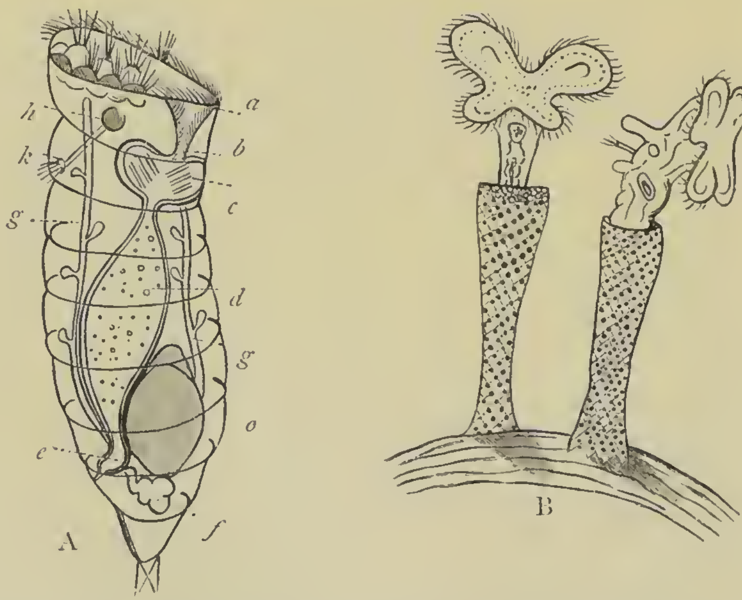

Fig. 160.—Rotifera. A, Diagrammatic representation of *Hydatina senta* (generalised from Pritchard): *a* Depression ("buccal funnel") in the ciliated disc leading to the digestive canal; *b* Mouth; *c* Pharyngeal bulb or mastax, with the masticatory apparatus; *d* Stomach; *e* Cloaca; *f* Contractile bladder; *g g* Respiratory or water-vascular tubes; *h* Nerve-ganglion, giving filament to ciliated pit (*k*); *o* Ovary. B, *Melicerta ringens*. (After Gosse.)

and *Floscularia*. They are usually simple, but are occasionally composite, forming colonies, as in *Megalotrocha*. As a rule, the male and female *Rotifera* differ greatly from one another, the males being smaller than the females, destitute of any masticatory or digestive apparatus, and more or less closely

resembling the young form of the species. The most characteristic organ in the great majority of the *Rotifera*, is the so-called "wheel-organ," or "trochal disc," which is always situated at the cephalic or distal end of the body, and consists of a retractile disc, surrounded by a circlet of cilia, which, when in action, vibrate so rapidly as to produce the illusory impression that the entire disc is rotating.

The disc, which carries the cilia, is capable of eversion and inversion, and may be circular, reniform, bilobed, four-lobed, or divided into several lobes. It serves the purpose of locomotion in the free-swimming forms, acting somewhat like the propeller of a screw-steamer; and in all it serves to produce currents in the water, which convey the food to the mouth.

In *Chætonotus*, and some other forms (*Gastrotrichæ*), there is no true wheel-organ, capable of protrusion and retraction, but the cilia are variously disposed over the surface of the body. The *Chætonoti* or Hairy-backed Animalcules have no jaws, and have the ventral surface of the body clothed with cilia. They have often been placed in the *Turbellaria*, but there seem to be good reasons for regarding them as an aberrant group of *Rotatoria*. *Balatro* and *Apsilus* are non-ciliated in the adult condition.

The body is often imperfectly segmented externally, and its proximal extremity is variously modified, constituting what has been called the "foot." In such fixed Rotifers as *Melicerta* (fig. 160, B), the foot is not retractile, and terminates in a disc of attachment. On the other hand, in most free Rotifers the "foot" is more or less retractile, sometimes telescopic, and usually ends in a pair of diverging processes or "toes" (fig. 160, A). By means of these, the animal can either creep about, or can fix itself temporarily to foreign objects through the medium of a viscid secretion produced by the so-called "foot-glands."

In a depression on the ventral side of the ciliated disc is the oral opening, which conducts by the so-called "buccal funnel" to a pharynx, which is surrounded by a muscular covering or "mastax." Within the pharynx is placed a complicated masticatory apparatus, consisting essentially of two hammer-like structures ("mallei") and a central anvil-like piece ("incus"), all the parts of which are set in motion by proper muscles. The pharynx opens by a short gullet into a simple sac-like stomach, with which are connected "gastric glands," possibly representing a liver. The intestine is short, and terminates behind in a dilated chamber or "cloaca," which forms the common outlet of the digestive, generative, and water-vascular systems, and opens by a dorsally-placed median aperture at the commencement of the "foot." In some forms (*e.g.*,

Asplanchna) the digestive canal ends blindly; while the males, as before remarked, are destitute of any alimentary canal.

The so-called "water-vascular" system consists of two lateral tubes (sometimes called the "respiratory tubes"), which are filled with a watery fluid, and carry on their sides a series of ovate or pyriform, internally-ciliated vesicles or short tubes. These open into the body-cavity by means of their funnel-shaped ciliated extremities. The two lateral canals generally open into a so-called "contractile bladder," which exhibits rhythmical contractions and dilatations, and which opens into the cloaca. This peculiar system of vessels has been compared with the "segmental organs" of Annelides, and is usually believed to be excretory in function.

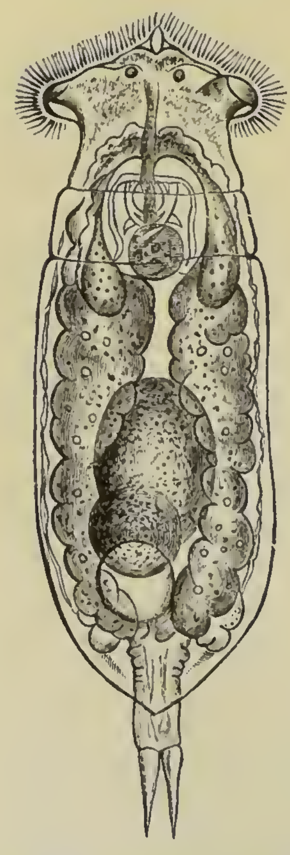

Fig. 161.—Rotifera. *Eosphora aurita*, one of the Wheel-animalcules. Enlarged about 250 diameters. (After Gosse.)

There is no proper vascular system, nor are definite respiratory organs developed; but the perivisceral cavity is filled with a corpusculated fluid, corresponding with the blood of the higher animals.

The nervous system is in the form of a usually bilobed "cerebral" ganglion, placed dorsally above the œsophagus, and of relatively remarkably large size. Closely connected with the central mass of the nervous system is an unpaired or paired pigment-spot, which is an organ of vision. Other sense-organs, probably tactile, are often present, in the form of two knobs surmounted by bristles, and placed at the back of the head.

The male reproductive organs consist of a sac-like testis, which opens posteriorly. The female reproductive organs consist of a large ovary, the duct of which opens into the cloaca. The ova which are produced in autumn ("winter-eggs") have thick shells, and are fertilised in the usual manner. The so-called "summer ova," on the other hand, have thin shells, and appear to be developed parthenogenetically.

The typical group of the *Rotifera* is that of the *Notommatina* (*Hydatinea* of Ehrenberg). In this group (fig. 161) the animals are all permanently free, and are never combined into colonies, while the integument is flexible, and the body is never encased in a tube.

Stephanoceros and *Floscularia*, on the other hand, are fixed, and are enclosed in a gelatinous tube which is secreted by the animal. *Melicerta* (fig. 160, B) inhabits a tubular case, which the animal forms for itself by means of a special organ for the purpose; whilst *Polyarthra* and *Triarthra* are protected by a stiff shell, or "lorica."

In *Polyarthra* there are ensiform fins, jointed to the body by distinct shelly tubercles, and moved by powerful muscles. These natatory organs are considered by Mr Gosse to be homologous with the articulated limbs of the *Arthropoda*. Locomotive appendages are also present in *Triarthra* and *Pedalion*.

In *Asplanchna*, whilst the masticatory organs, gullet, and stomach are well developed, there is no intestine, the stomach "hanging like a globe in the centre of the body-cavity," but not communicating with the body-cavity.

The genus *Echinoderes*, lastly, includes certain minute marine organisms, in which the body is imperfectly segmented, but there are no limbs. The anterior segment of the body is furnished with hooklets, and constitutes a protrusible proboscis. The genus forms a link between the Scolecids and the higher Annulosa.

As regards their distribution in space, the *Rotifera* have an almost world-wide range. The majority of the known forms are inhabitants of fresh water, but a few live in the sea.

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CHAPTER XXV.

ANARTHROPODA.

THE division *Anarthropoda* includes the three classes of the Spoon-worms (*Gephyrea*), the Ringed Worms (*Annelida*), and the Arrow-worms (*Chætognatha*), and constitutes the highest section of the "Vermes" of modern zoologists. To these a fourth class may be added for the reception of the small and aberrant group of the *Myzostomida*. The members of this division are characterised by the possession of an elongated worm-like body, which usually shows a conspicuous composition out of similar, or nearly similar, segments, which, however, are not numerically definite. The nervous system, in

the typical members of the division, consists of a ventrally-placed double chain of ganglia, one pair of ganglia corresponding with each segment, the anterior pair being placed above the gullet, and all being united by longitudinal commissures. Lateral locomotive appendages are usually present, but are not composed of successive joints, nor are articulated to the body. A true blood-vascular system is not developed; but there is usually a closed system of "pseudohæmal" vessels.

Gephyrea.

Class I. Gephyrea = (*Sipunculoidea*).—*Vermiform marine animals, without distinct external segmentation, and destitute of lateral appendages (with the occasional exception of bristles). There is a single, non-ganglionated ventral nerve-cord, connected by commissures with a supra-œsophageal ganglion. A pseudo-hæmal system of vessels is present, and the sexes are distinct.*

The members of this class are generally known as "Spoon-worms," and they form a connecting link between the Echinoderms and the Annelides. The body in the Spoon-worms is

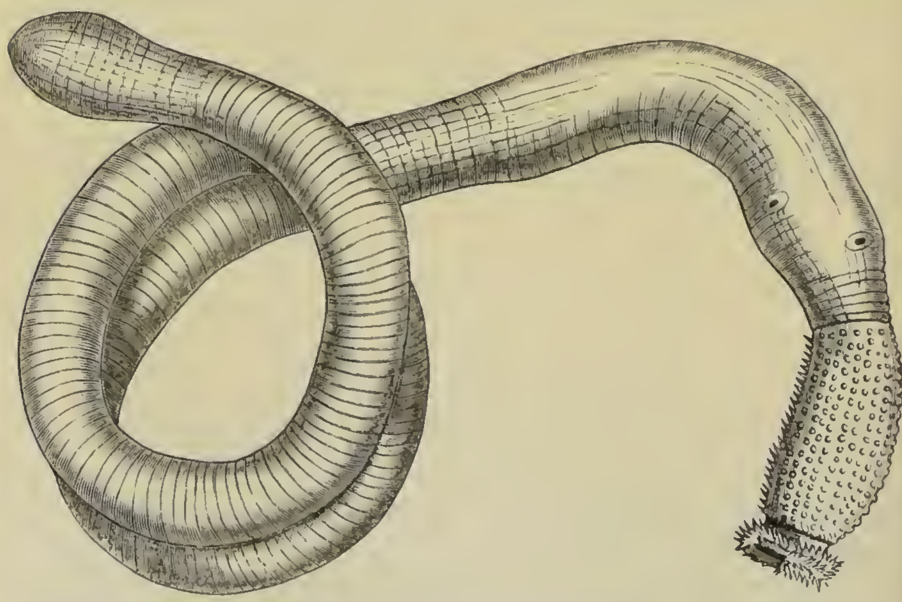

Fig. 162.—Gephyrea. *Sipunculus indicus*, of the natural size. (After Keferstein.)

worm-like, and the integument may be more or less ringed, though definite segmentation does not occur. In some cases the skin is furnished with bristles (as in *Echiurus*); while in *Chætoderma* the integument develops calcareous spines. The outer layer of the skin is chitinous, and is underlaid by a

glandular layer, with an inferior muscular stratum of longitudinal and circular muscular fibres.

The alimentary canal begins in a funnel-shaped pharynx, which opens into a long digestive tube, the middle portion of which is spirally coiled. The last portion of the intestine (rectum) opens by a terminal or dorsally-placed anus. The mouth is anterior, and is often placed ventrally at the base of a contractile proboscis, or may be surrounded by ciliated tentacles (as in *Sipunculus*).

The body-cavity is filled with a corpusculated "perivisceral fluid," often of a reddish colour, which corresponds with the blood of the higher animals. A system of pseudohæmal vessels is also present, filled with a colourless or red fluid, and furnished with longitudinally-placed contractile dilatations. Respiration appears to be effected by means of the skin principally, assisted by the oral tentacles, when these structures are present. Some Gephyreans (as, for example, *Echiurus*) possess also a pair of singular tufted tubes, which spring from the last part of the intestine, and communicate on the other hand with the body-cavity by ciliated funnel-shaped apertures. These so-called "anal vesicles" have been compared with the "respiratory tree" of Holothurians; but they are probably excretory in function. Anteriorly there are also from one to three (rarely six) pairs of tubular organs, which open by pores on the ventral surface, and communicate with the body-cavity by ciliated apertures. These are usually regarded as corresponding with the "segmental organs" ("nephridia") of the Annelides, and one of their functions is to act as efferent ducts to the reproductive organs.

Fig. 163.—Larva of *Phascolosoma elongatum*, after development has proceeded to some extent.

The nervous system consists of a cerebral ganglion, sometimes connected with eye-spots, a pharyngeal nerve-collar, and an unpaired ventral cord, which, though mostly covered with nerve-cells, has no distinct ganglia developed upon it.

As regards their development, the larva (fig. 163) has generally the characters of the so-called "trochosphere," which is the usual form of embryo among the Annelides. It consists of a præ-oral and post-oral region, sometimes equal, sometimes unequal in size, separated by a double or single belt of cilia, by means of which the larva swims actively. In the aber-

rant *Phoronis* the larva was originally described under the name of *Actinotrocha*. It is distinguished by the possession of an oblique ring of ciliated tentacles placed behind the mouth.

The *Gephyrea* are all inhabitants of the sea, living mostly in sand or mud, or in crevices in the rocks, sometimes protecting themselves within the empty shells of Molluscs, or secreting a chitinous tube. In some forms such as *Echiurus* and *Sternaspis* (*Gephyrea chætifera*), there are two ventral setæ, and sometimes rings of bristles at the hinder end of the body. In other forms, such as *Sipunculus* and *Priapulus* (*Gephyrea achæta*), the skin is destitute of bristles. Lastly, a third group (*Tubicola*) includes the singular genus *Phoronis*, in which the body is protected by a chitinous tube, and the mouth is surrounded by a horse-shoe-shaped circlet of tentacles.

MYZOSTOMIDA.

CLASS II. MYZOSTOMIDA.—This class comprises only certain small, symmetrical, unsegmented animals, with a more or less discoidal body, which carries on its ventral surface five pairs of unsegmented movable feet ("parapodia"), each of which has a hook for grasping. The alimentary canal has both an oral and an anal aperture, and the stomach is usually branched. The ova are liberated through the anus. The sexes are usually united in the same individual, though this is not invariably the case. The nervous system has the form of a ventral ganglion situated below the intestine, which is connected with a pharyngeal nerve-collar in front, but the latter is without supra-œsophageal ganglia. There are no circulatory, respiratory, nor excretory organs.

The principal genus contained in this group is *Myzostoma*, comprising small discoid animals, which are parasitic on and in Crinoids. They usually form cysts, somewhat like plant-galls, upon the calyx, arms, or pinnules of Feather-stars or other Crinoids; but some types crawl about upon their host. In a number of cases, fossil Crinoids have been found to have the arms or pinnules distorted by the cysts of *Myzostoma*.

ANNELIDA.

CLASS III. ANNELIDA (= *Annulata*).—The *Annelida* are vermiform animals, distinguished from the preceding by the possession of *distinct external segmentation; the nervous system is composed of a ventral, double, gangliated cord, with an œsophageal collar and præ-œsophageal pair of ganglia.*

This class comprises elongated worm-like animals, in which the integument is always soft, and the body is more or less distinctly segmented, each segment usually corresponding with a single pair of ganglia in the ventral cord. All the segments are similar to one another except those at the anterior and posterior extremities of the body. Each segment may also be

provided with a pair of lateral appendages, but these are never articulated to the body, and are never so modified in the region of the head as to be converted into masticatory organs.

In the higher *Annelida* each segment (fig. 164) consists of

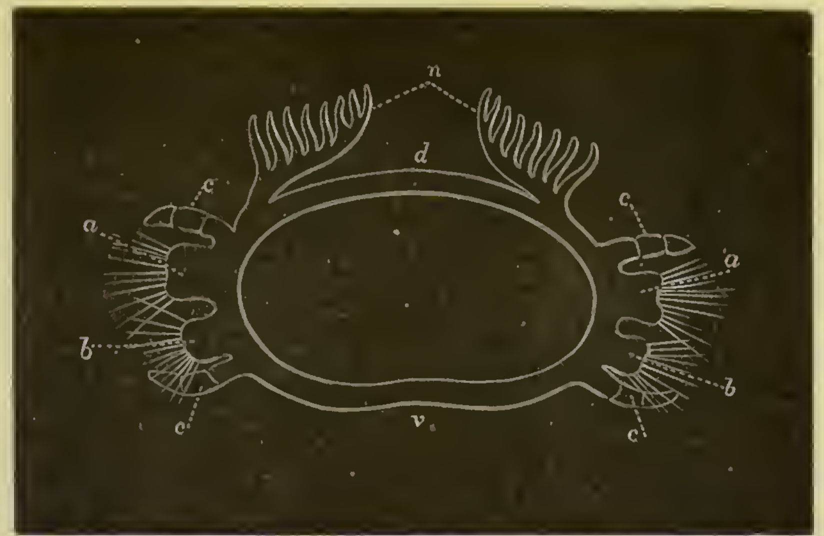

Fig. 164.—Diagrammatic transverse section of an Annelide. *d* Dorsal arc; *v* Ventral arc; *n* Branchiæ; *a* Notopodium, or dorsal oar; *b* Neuropodium, or ventral oar, both carrying setæ and a jointed cirrhus (*c*).

two arches, termed, from their position, respectively the "dorsal arc" and the "ventral arc"; and each bears two lateral processes, or "foot-tubercles" (*parapodia*), one on each side. Each "foot-tubercle" is typically double, being composed of an upper process, called the "notopodium," or "dorsal oar," and a lower process termed the "neuropodium," or "ventral oar"; but these may be fused together. The foot-tubercles, likewise, support bristles, or "setæ," and a soft cylindrical appendage, which is termed the "cirrhus" (fig. 164, *c*).

The number of the segments varies much, being as many as 400 in *Eunice gigantea;* and, generally, there is not a distinct head which is separable from the succeeding rings of the body. When such a distinct head appears to be present, it is not comparable with the head of the *Arthropoda*, but is really a greatly modified præ-oral region, or "prostomium," as is shown by the position of the mouth. The "prostomium" or "cephalic lobe" is placed in front of the mouth, and often carries "tentacles" above and tactile processes or "palpi" below.

The digestive system of the Annelides consists of a mouth, sometimes armed with horny jaws, a gullet, stomach, intestine, and a distinct anus. Except in the *Hirudinea*, the alimentary

canal is suspended in a capacious perivisceral space, divided into compartments by more or less complete partitions. The alimentary canal is, with one or two exceptions, not convoluted, and extends straight from the mouth to the anus; but lateral diverticula are often present.

The body-cavity contains a corpusculated fluid, which corresponds with the blood of the higher animals. In all Annelides, however, there exists a special vascular system, consisting of closed vessels, often with contractile cavities appended to them, filled with a generally coloured fluid, which only occasionally contains floating corpuscles. This system of vessels is usually termed the "pseudohæmal" system. In many cases it communicates with the body-cavity; and when there are definite respiratory organs it sends branches to these. The pseudohæmal fluid thus plays an important part in the respiration of Annelides. Distinct breathing-organs, in the form of branchiæ, are present in many marine Annelides; but in other cases the functions of respiration is discharged by the general surface of the body.

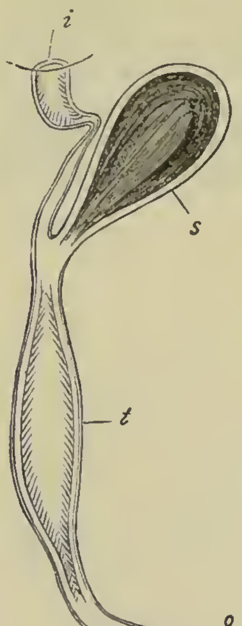

Fig. 165.—Segmental organ of a Chætopodous Annelide (*Alciopa*), enlarged. *o* External aperture or stigma; *t* Tubular and ciliated portion of the segmental organ; *s* Seminal receptacle; *i* Ciliated infundibulum opening into the body-cavity. (After Claparède.)

The excretory organs of the Annelides are the so-called "segmental organs," or "nephridia." In their simplest form (as in the ordinary Leeches), each segmental organ is in the form of a much-folded tube, partly labyrinthic, partly vesicular, often with an appended cæcum, and opening externally by a distinct aperture or "stigma," but having no internal communication with the body-cavity. In these cases, the segmental organs may be regarded as representing the kidneys of the higher animals. In the higher *Annelida*, the segmental organs are usually in part subordinated to the function of reproduction. In these cases (fig. 165) the inner surface of the convoluted tube, which constitutes the segmental organ, is ciliated; and the tube not only opens exteriorly by a distinct "stigma," but also communicates internally with the perivisceral cavity by a widely patulous, trumpet-shaped, internally-ciliated infundibulum

(fig. 165, *i*), by which the products of generation may be taken up and conveyed to the outer medium. Very usually, also, there are appended to the tube of the segmental organ blind glandular pouches, which represent the kidneys, or in other cases cæcal appendices (fig. 165, *s*) for storing up the generative products.

The nervous system consists of a double, ventral, gangliated cord, which is traversed anteriorly by the œsophagus; the "præ-œsophageal," or "cerebral," ganglia being connected by lateral cords or commissures with the "post-œsophageal" ganglia. Pigment-spots, or "ocelli," sometimes of high organisation, are present in many, generally upon the proboscis, sometimes in each segment, or on the branchiæ, or on the tail; and the head often supports two or more feelers, which differ from the "antennæ" of Insects and Crustacea in not being jointed.

The sexes in the *Annelida* are sometimes distinct, and sometimes united in the same individual. The embryos are almost universally ciliated, and even in the adult cilia are almost always, if not always, present—in both of which respects this class differs from the *Arthropoda*.

The *Annelida* may be divided into two sections, characterised by the presence or absence of external respiratory organs or branchiæ. The Abranchiate section comprises the Leeches and the Earth-worms; whilst the Branchiate division includes the Tube-worms (*Tubicola*) and the Sand-worms (*Errantia*). The *Annelida* are also often divided into two sections, called *Chætopoda* and *Discophora*, according as locomotion is effected by chitinous setæ (Earth-worms, Tube-worms, and Sand-worms) or by suctorial discs (Leeches).

CHAPTER XXVI.

ORDERS OF ANNELIDA.

ORDER I. HIRUDINEA (*Discophora* or *Suctoria*).—This order includes the Leeches, and is characterised by *the possession of a locomotive and adhesive sucker, posteriorly or at both extremities, and by the absence of bristles and foot-tubercles. The sexes are united in the same individual, and the young do not pass through any metamorphosis.*

The Leeches are vermiform, mostly aquatic animals, inhabiting both fresh and salt water. Locomotion is effected either by swimming by means of a serpentine bending of the body, or by means of one or two suctorial discs. In those forms in which there is only a single sucker (posterior), the head or anterior extremity of the body can be converted into a suctorial disc. The body is ringed, nearly one hundred annulations being present in the common Leech; but these external rings do not correspond with the true segments of the body, and, with rare exceptions (*Branchellion*), there are no lateral appendages of any kind. The mouth is placed at the front end of the body, and may or may not be furnished with teeth. The pharynx is muscular; the gullet leads into a stomach with, usually, capacious lateral cæca (fig. 167, B); and the anus is placed dorsally, in front of the posterior sucker. The alimentary canal is united with the integument by a spongy tissue, formed of vascular sinuses, which more or less completely obliterate the body-cavity, and in which the blood circulates. The pseudohæmal system generally consists of four principal longitudinal trunks, devoid of special dilatations. Respiration is carried on by the soft integument, definite respiratory organs not being developed. The "segmental organs" are in the form of a larger or smaller number of coiled tubes (fig. 167, B), which open upon the abdominal surface by so many pores or "stigmata." The function of these tubes appears to be excretory, and in the majority of the *Hirudinea* they are closed internally, and only open externally by the "stigmata." In some of the *Hirudinea*, however, the "segmental organs" agree with those of the great majority of the Annelides in not only opening externally, but in also communicating internally with the perivisceral cavity. One pair of segmental organs corresponds with a body-segment; but it is only in certain segments, in the middle region of the body, that these organs are developed. In many cases seventeen pairs of segmental organs are present, as in the Medicinal Leech; but in other cases the number of these structures is much smaller. In no case do the segmental organs serve to convey the generative products to the exterior.

The nervous system consists of a præ-œsophageal ganglion, which gives branches to a number of simple eyes, or ocelli, which are placed on the head, and which is united by lateral œsophageal cords to the ventral gangliated chain. The ventral chain of the common Leech carries twenty-three successive pairs of ganglia, marking the composition of the body out of the same number of segments; but the first and last post-

œsophageal ganglia are really composed, each, of several ganglia fused together, the real number of segments being more than twenty-three.

The sexes are united in the *Hirudinea*, and the generative

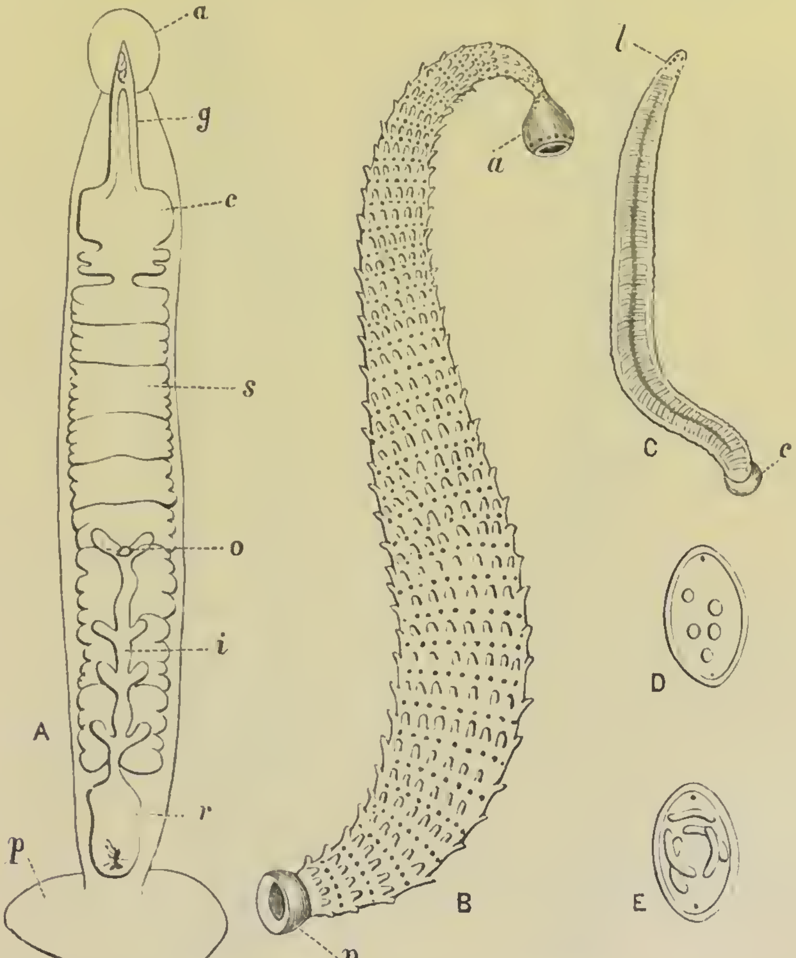

Fig. 166.—Hirudinea. A, Semi-diagrammatic view of *Piscicola geometrica*, enlarged: *a* The anterior, and *p* the posterior sucker; *g* The pharynx, with the proboscis; *c* The proventriculus; *s* The proper stomach; *o* Sphincter separating the stomach from the intestine; *i* Intestine, with lateral cæca; *r* Rectum, terminating in the aperture of the anus. B, *Pontobdella muricata*, of the natural size: *a* Anterior, and *p* posterior sucker. C, *Nephelis octoculata*, viewed from above, of the natural size: *l* Upper lip, carrying the eye-spots; *c* Posterior sucker. D, Cocoon of the preceding, with eggs, enlarged. E, An older cocoon of the same, with young leeches, enlarged. (After Leydig and Moquin-Tandon.)

openings are unpaired. The testes open by a *vas deferens* on each side into a coiled vesicula seminalis, connected with a prostatic gland, and the penis is azygous. The vaginal opening is placed behind the male generative aperture. The ova

are deposited in delicate chitinous capsules or "cocoons" (fig. 166, D), and the young do not undergo any marked metamorphosis, being in most cases essentially similar to the adult except in size.

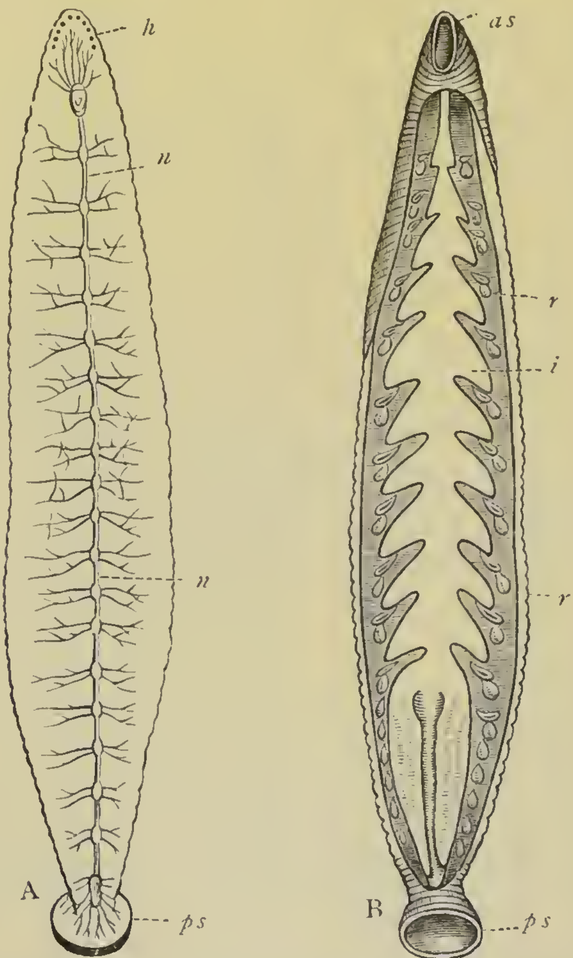

Fig. 167.—A Diagram of the Leech, showing the nervous system, and the ten eyes placed on the top of the head. B, The Leech dissected to show the alimentary canal (*i*), and the "segmental organs" (*r r*); *as* Anterior sucker; *ps* Hinder sucker; *n n* Nervous system; *h* Head, carrying the eye-spots.

In the Medicinal Leech (*Hirudo* or *Sanguisuga officinalis*), the body exhibits externally nearly one hundred annulations, of which from three to five correspond with a single *body-segment*. The hinder margins of the true segments are marked out by the apertures of the seventeen pairs of segmental organs. The anterior and posterior suckers also represent each a series of coalescent segments (the anterior containing four, and the posterior seven segments). The anterior sucker is perforated centrally by the mouth, and is prolonged above into a lanceolate lip, the upper surface of which bears ten minute eyes arranged in an ellipse. The posterior sucker

is imperforate, round, and constricted off from the body, and just in front of it, upon the dorsal surface, is the opening of the anus.

The mouth contains three minute semilunar serrated jaws, arranged in a triradiate manner (fig. 168, *b* and *c*). It opens into a small, externally villous pharynx, continued backwards into a digestive sac, the so-called "stomach," which occupies the greater part of the body. The stomach is sacculated, and carries eleven pouches on each side, the first pair of these being the smallest, while the last are very long, and are directed backwards in the axis of the body (fig. 167, B). Between the last pair of diverticula is seen the short intestine, which terminates at the dorsally-placed anus.

The body-cavity is not completely differentiated from the vascular system; but there are transverse partitions which run from the intervals between the gastric pouches to the body-wall, and the spaces between these are filled with spongy tissue containing pseudohæmal sinuses. The principal pseudohæmal vessels are (1) a median dorsal trunk, (2) a median ventral trunk, in which lies the ventral nerve-chain, and (3) two wide longitudinal trunks, one on each side of the body. The pseudohæmal fluid is red, and non-corpusculated.

There are seventeen segmental organs on each side of the body. Each consists of an external saccular portion, which opens on the exterior by a ventrally-placed pore, and an internal, tubular, looped portion (fig, 167, B). Certain of the segmental organs send *blind* diverticula to the testes; but their inner ends are closed, the segmental tubes thus neither communicating with a body-cavity, nor being connected with reproduction.

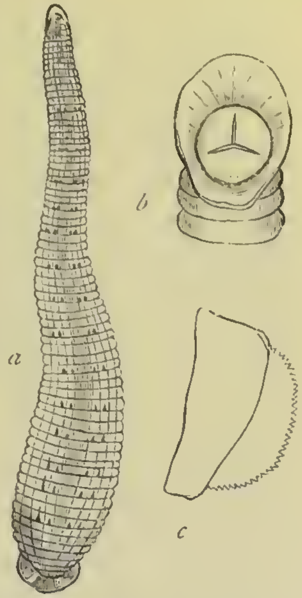

Fig. 168.—Hirudinea. *a* The Medicinal Leech (*Sanguisuga officinalis*), natural size; *b* Anterior extremity of the same magnified, showing the sucker and triradiate jaws; *c* One of the jaws detached, showing the semicircular toothed margin.

The nervous system consists of a double ventral gangliated chain, composed of one supra-œsophageal and twenty-two post-œsophageal ganglia, and their commissures. The first and last of the post-œsophageal ganglia are larger than the rest, and represent, each, several ganglia fused together. The whole of the post-œsophageal portion of the nerve-chain is enclosed in the ventral blood-sinus.

The reproductive organs occupy a special region of the body, which becomes swollen at the breeding season, and is termed the "clitellum." The animal is hermaphrodite, and the male organs consist of (1) a cirriform penis, the aperture for the protrusion of which is placed between the 24th and 25th annuli. The penis passes internally into (2) a swollen and glandular portion (the prostate), into which open (3) two ejaculatory ducts, one on each side of the body. The ejaculatory ducts are derived from (4) two convoluted pyriform "vesiculæ seminales," in which the spermatozoa are coated into "spermatophores." Each vesicula seminalis (or "epididymis") opens finally into (5) a long vas deferens, to which are appended by short stalks nine globular testes. The female generative organs consist of (1) two minute ovaries, the ducts of which unite to form (2) a single oviduct. This opens into (3) a wider muscular tube or vagina, the external aperture of which is placed between the 29th and 30th annuli.

A few Leeches are not aquatic in their habits, but are found in damp situations on land, mostly in hot countries (India, Ceylon, South America, &c.) The common "Horse-leech" (*Hæmopsis*) has numerous blunt teeth, which are too weak to penetrate the skin, but will pierce mucous membranes. It inhabits ponds and marshes, and attaches itself to the throat of animals when drinking. *Aulostomum gulo*, also often called the "Horse-leech," feeds principally upon fresh-water shell-fish. The genera *Pontobdella* and *Piscicola* belong to a section of the Leeches (*Rhynchobdellidæ*) in which there is a protrusible proboscis. The *Piscicolæ* attach themselves parasitically to the gills of fresh-water fishes. The *Pontobdellæ* are marine, a well-known example being the common "Skate-sucker" (*P. muricata*), in which the skin is tuberculated, and the anterior sucker is marked off by a constriction from the body (fig. 166, B). It lives parasitically on Skates and other sea-fishes. Also belonging to this section are the little fresh-water Leeches of the genus *Clepsine*, which feed on Water-snails. They carry about their young, attached to the under surface of the body by their posterior suckers, for some time after birth. Lastly, *Branchiobdella* lives upon the gills of Crustaceans, and *Branchellion* infests the gills of various fishes, such as the Turbot.

ORDER II. OLIGOCHÆTA.—The members of this order, comprising the Earth-worms and their allies, are distinguished by the fact that *their locomotive appendages are in the form of chitinous setæ or bristles attached in rows to the sides and ventral surface of the body. No branchiæ are present. They are all hermaphrodite; and the young pass through no metamorphosis.* The *Oligochæta* are divided into the two groups of the *Terricolæ* or Earth-worms, and the *Limicolæ* or Mud-worms and Water-worms (*Sænuridæ* and *Naïdidæ*).

The body in the *Oligochæta* is segmented, and the anterior segment is prolonged in front of the mouth into a "prostomium" or "cephalic lobe." The locomotive organs are in the form of short bristles, or "setæ" (fig. 169, A), which are arranged in rows on the lower and lateral surfaces of the animal, and are never supported upon special outgrowths or "parapodia."

The mouth is toothless, and opens into a muscular pharynx, which in turn opens into an œsophagus, to which special glandular organs are often appended. A more or less complicated stomach is present, and the intestine ends in a terminal anus. The body-cavity is subdivided by membranous partitions, corresponding with the different segments of the body, and is filled with a corpusculated "perivisceral fluid."

The pseudohæmal vessels are well developed, and are often furnished with contractile dilatations or "hearts" (fig. 169, *h*). The pseudohæmal fluid is generally red in colour. Specialised

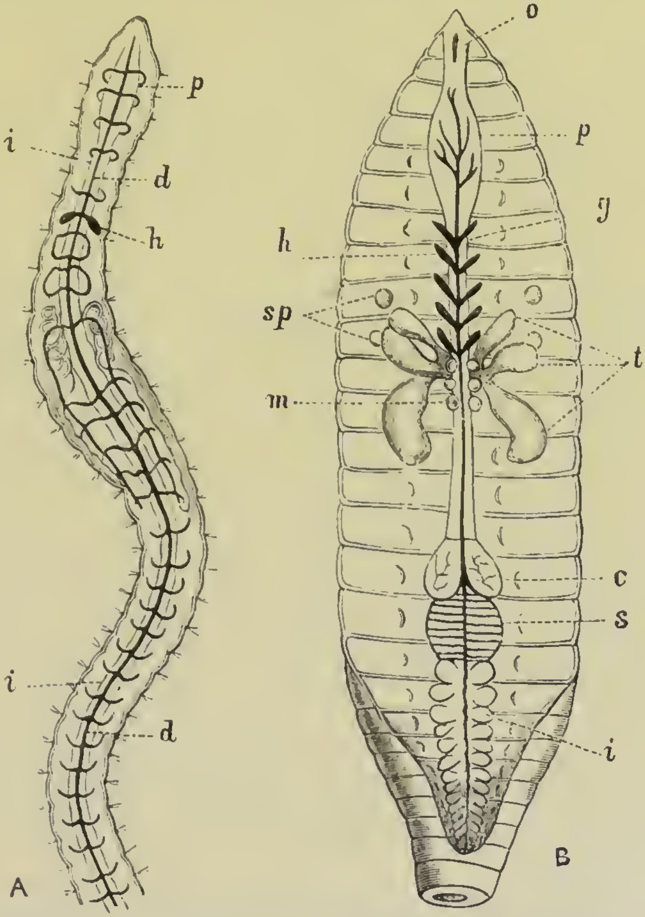

Fig. 169.—Oligochæta. A, Anterior portion of *Tubifex rivulorum*, enlarged: *p* Pharynx; *i i* Alimentary canal; *d d* Dorsal vessel; *h* One of the "hearts" or contractile dilatations of the pseudohæmal vessels. B, Anterior portion of *Lumbricus terrestris*, laid open and enlarged: *o* Mouth; *p* Pharynx; *g* Gullet; *m* Œsophageal glands; *c* Proventriculus; *s* Gizzard; *i* Intestine; *h* One of the "hearts" borne on the side of the dorsal vessel; *t* Seminal reservoirs; *sp* Spermathecæ. (After Lankester.)

organs of respiration are not developed. The "segmental organs" are largely developed, and have the form of coiled tubes, which open externally by ventrally-placed pores, and communicate internally with the body-cavity by ciliated apertures. None of the segmental organs in the Earth-worms officiate as ducts to the reproductive organs; but the ducts which convey the generative products to the exterior in the Water-worms are modified segmental organs.

The nervous system is of the normal Annelidan type, and

there may or may not be simple organs of vision in the form of pigment-spots. The reproductive organs of the two sexes are united in the same individual, and are very complex. Two pairs of testes, with vasa deferentia, and a pair of ovaries, with oviducts, are present, and there are various accessory generative organs as well. The external openings of the vasa deferentia and oviducts are placed on the ventral surface of the body, far forward, and behind these exists a thickened glandular zone or "clitellum," which is connected with copulation, and becomes much swollen at the breeding season. Development is direct, and the young pass through no metamorphosis.

The body of the common Earthworm (*Lumbricus terrestris*) is cylindrical, attenuated at both ends, and exhibiting a large number of narrow annulations or segments. About the middle third of the body (commencing with a segment between the 29th and 32d) begins the swollen region of the "clitellum," or "cingulum," which is made up of about six partially-fused segments, and is of a lighter colour than the rest of the worm. The anterior portion of the clitellum is furnished with a highly glandular integument, and the entire region is connected with reproduction, its setæ being specially modified for adhesion.

The locomotive setæ are arranged ventro-laterally in four longitudinal double rows, two rows being placed external to the middle line, and two rows being lateral. The first segment, or "cephalic lobe," is small and pointed, and presents on its lower surface the aperture of the edentulous mouth. Placed in the middle line of the back, except in the most anterior rings, is a row of minute pores leading into the body-cavity. The opening of the anus is terminal.

The body-cavity is filled with a colourless or slightly milky fluid, which contains numerous floating corpuscles, some of which exhibit amœboid movements. The perivisceral space is divided into a series of compartments, separated by transverse, membranous, "mesenteric" partitions, which correspond with the successive body-segments, and are perforated by the alimentary tube.

The minute edentulous mouth, on the ventral side of the first segment, opens into a buccal cavity, passing backwards into a muscular pharynx (fig. 169, *p*), which in turn leads into a straight œsophagus, to the sides of which are appended special glandular organs. The gullet opens into a dark-coloured cordate "crop" (fig. 169, *c*), behind which is a thick-walled muscular "gizzard." The intestine is straight, with lateral sacculated pouches in the first few segments behind the gizzard, and having its dorsal wall pushed inwards to form a longitudinal ridge ("typhlosole"), which projects into the cavity of the intestine. The exterior surface of the intestine is covered with a layer of brownish-yellow "hepatic" cells, of undetermined function.

There are no differentiated respiratory organs. The principal pseudohæmal trunks are (1) a "supra-intestinal" vessel, running along the dorsal side of the alimentary canal; (2) a corresponding "sub-intestinal" vessel, running along the ventral side of the digestive tube; and (3) a group of "sub-neural" vessels, of which the chief is placed beneath the ventral nerve-chain. The lateral vessels which connect the supra-intestinal and sub-intestinal trunks are dilated in the segments from the 7th to the 11th into contractile chambers or "hearts" (fig. 169, B, *h*).

The nervous system consists of a bilobed supra-œsophageal ganglion, in the third segment, united by lateral commissures with a gangliated ventral nerve-chain. No special sense-organs are present.

The segmental organs or nephridia have the form of looped tubes, of which each segment, except the first three and the last, contains a pair. The external openings of the segmental organs are minute pores placed on the ventral surface just external to the outer setæ of the middle row of bristles. Internally, each segmental tube ends in a funnel-shaped ciliated aperture, which opens into the perivisceral compartment next in front of that in which the looped portion of the nephridium is situated.

The male and female organs of reproduction are united in the same individual. The male organs are as follows: (1) Two pair of minute testes, situated in the 10th and 11th segments. (2) Three pairs of large membranous "seminal reservoirs" in the 9th, 10th, and 11th rings (fig. 169, *t*), which open into two pairs of similar reservoirs placed in the middle line of the 10th and 11th rings. Each of these median seminal reservoirs contains a folded membranous funnel ("seminal funnel"), the mouth of each of these being directly over one of the testes. Minute ducts lead from these seminal funnels to a common vas deferens on each side, which is continued backwards to open by a minute external aperture on the 15th ring.

The female organs consist of (1) a pair of minute ovaries in the 13th segment; (2) two short oviducts, which have wide ciliated mouths placed opposite their respective ovaries, though not directly connected with them, and which open externally on the 14th segment; and (3) two pairs of globular sacs ("spermathecæ"), placed in the 9th and 10th segments and opening externally by minute pores (fig. 169, *sp*). These sacs are used for storing up the seminal fluid received from another worm in the act of reproduction. Just outside of the line of attachment of the seminal reservoirs there are, further, five pairs of minute glandular organs (the so-called "capsulogenous glands"), which secrete the horny covering of the cases or "cocoons," in which the eggs are deposited.

The *Oligochæta* are partly terrestrial, partly aquatic in their habits, the latter forms being found in both fresh and salt water. A few forms are parasitic. The terrestrial forms are the Earth-worms (*Lumbricidæ*), and a common example of the fresh-water forms is the familiar *Tubifex rivulorum* of our streams (fig. 169, A). Some of the fresh-water *Oligochæta* (*Naïdidæ*) have the power of producing new individuals by a process of gemmation; but they lose this power when the reproductive organs become developed. The zoöids produced in this way remain connected with one another in chains for some time, but they ultimately become separate and assume the characters of adult individuals.

ORDER III. POLYCHÆTA.—This order includes *marine Annelides, in which there are fleshy lateral outgrowths of the body ("parapodia"), to which bunches of setæ are attached. The head is usually distinct, and branchiæ, in the form of external processes of the body, are usually developed. The sexes are almost always distinct, and there is a metamorphosis in development.*

The body in the Polychætous Annelides is divided into a

number of rings or segments, each of which, in the typical forms, possesses the following structure. The segment consists of two arches, a lower or "ventral arc," and an upper or "dorsal arc," with a "foot-tubercle" or "parapodium" on each side. Each foot-tubercle consists of an upper process, or "notopodium," and a lower process, or "neuropodium," each of which carries a tuft of bristles, or "setæ," (rarely, a single bristle), and a species of tentacle termed the "cirrhus" (fig. 170, B).

In a few forms parapodia are absent, as also the setæ may

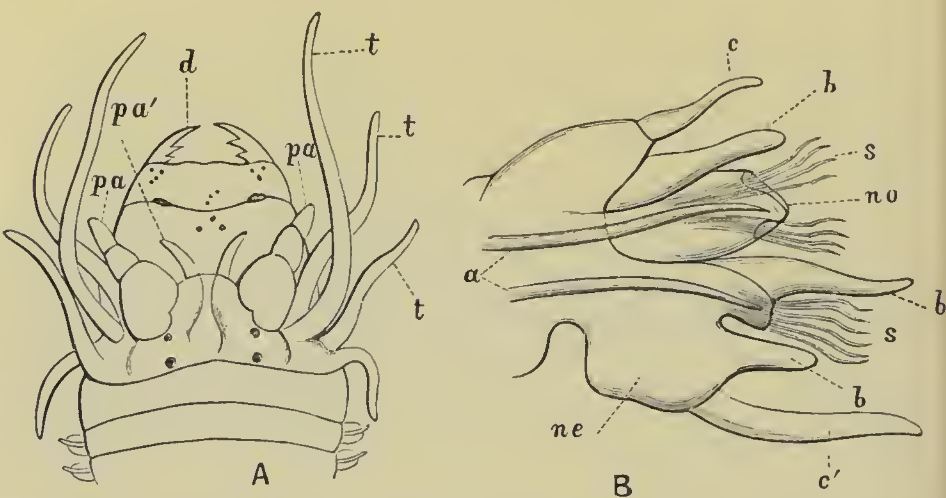

Fig. 170.—Annelida. A, Head of *Nereis incerta*, viewed from beneath, and enlarged (after Quatrefages): *d* The principal pair of chitinous jaws (the dark dots on the lobe behind these are smaller denticles); *pa'* Internal pair of palpi; *pa* External or greater pair of palpi; *t t t* Tentacles. B, Foot-tubercle of *Nereis*, enlarged: *no* Notopodium; *ne* Neuropodium; *c* Dorsal cirrhus; c' Ventral cirrhus; *b b b* Branchial filaments; *a* Aciculæ; *s s* Setæ attached to the dorsal and ventral oars.

be; and in one very aberrant type (viz., *Polygordius*), which is sometimes regarded as constituting a special division of Annelides, not only are both these sets of structures wanting, but even the external segmentation is lost.

The outer cuticular layer of the body is generally more or less chitinous, and is often iridescent. Below this is a muscular layer, by which the movements of the animal are effected, and which encloses the "perivisceral cavity." This cavity runs the whole length of the body, and is lined by a special, often ciliated membrane, which is reflected upon the alimentary canal and other internal organs. It is usually more or less subdivided by imperfect partitions, and is filled with an albuminous fluid containing floating corpuscles, and corresponding with the blood. This so-called "chylaqueous fluid"

"performs one of the functions of an internal skeleton, acting as the fulcrum or base of resistance to the cutaneous muscles, the power of voluntary motion being lost when the fluid is let out" (Owen).

The anterior extremity of the body (fig. 170, A) is usually so modified as to be distinctly recognisable as the head, and is provided with eyes, and with two or more feelers, which are not jointed, and are therefore not comparable with the antennæ of Crustacea and Insects. The mouth is placed on the inferior surface of the head, and is often furnished with one or more pairs of horny jaws, working laterally. The pharynx is muscular, and often forms a sort of proboscis, being provided with special muscles, by means of which it can be everted and again retracted. In most there is no distinction between stomach and intestine, and the alimentary tube often has appended to it lateral cæca, which may represent the liver.

The pseudohæmal system is usually well developed, and consists essentially of a long dorsal vessel, and a similar ventral one, connected by transverse branches, and sometimes furnished at the bases of the branchiæ with pulsating dilatations. The contained fluid is mostly red, but is yellow in *Aphrodite* and *Polynoe.* In a few forms the pseudohæmal system appears to be undeveloped.

Distinct respiratory organs may not be present; but usually "branchiæ" are developed in the form of leaf-like or tufted outgrowths from the body, which are richly supplied with pseudohæmal vessels. The sexes are mostly in different individuals, though some forms are hermaphrodite. The "segmental organs" are apparently sometimes absent; but when developed, they open internally into the body-cavity by means of wide ciliated apertures, and they commonly serve as efferent ducts to the generative organs. In many cases, the segmental organs (fig. 165), have glandular walls, and may be regarded as discharging the function of kidneys.

The Polychætous Annelides may be divided into two principal sections—*Tubicola* and *Errantia*—according as they inhabit a tube which they secrete for themselves, or have a free and wandering habit of life.

SUB-ORDER I. TUBICOLA.—The sedentary or "Tubicolous" forms of the *Polychæta* inhabit variously-formed tubes, to which they are not organically connected, and in which they can move freely by means of their setigerous foot-tubercles. Owing to their possession of an investing tube, branchiæ are only developed in the anterior region of the body (fig. 171), this being the only part which is ordinarily exposed to the

action of the sea-water; hence the *Tubicola* are sometimes called the "cephalobranchiate" Annelides. Owing to the abundant supply of pseudohæmal vessels which they receive, the branchial tufts are usually bright red in colour.

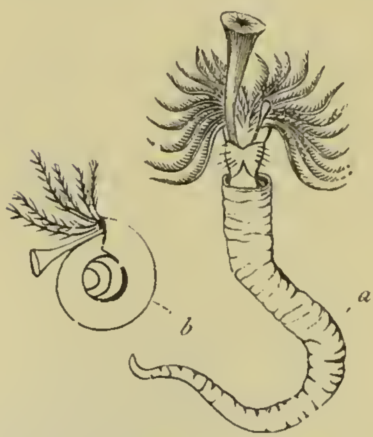

Fig. 171.—Tubicola. *a Serpula contortuplicata*, showing the branchiæ and operculum; *b Spirorbis communis.*

The protecting tube of the Tubicolous Annelides may be composed of carbonate of lime (*Serpula*), of grains of sand (*Sabellaria*), or of sand, pieces of shell, and other adventitious particles cemented together by a glutinous secretion from the body (*Terebella*); or it may be simply membranaceous or leathery (*Sabella*). Sometimes the tube is free and non-adherent (*Pectinaria*); more commonly it is attached to some submarine object by its apex or by one side (*Serpula* and *Spirorbis*). Sometimes the tube is single (*Spirorbis*); sometimes the animal is social, and the tubes are clustered together in larger or smaller masses (*Sabellaria*).

Reproduction in the *Tubicola* is generally sexual, the sexes being mostly in different individuals; but fission has also been noticed to occur. As regards their development, the young pass through a distinct metamorphosis. The larvæ (fig. 172, A and D) are freely locomotive, furnished with eye-spots, and swimming actively by means of cilia, which are principally aggregated into two rings or circlets, one placed on the head, the other at the hinder end of the body. The tentacles are developed at an early period, and the larva undergoes segmentation. Finally, the cilia disappear, the larva becomes stationary, and the protective tube of the adult is secreted. The young Tubicolar Annelide thus resembles the permanent condition of the Errant forms; and the stationary condition of the adult, accompanied by the loss of its sense-organs, may be regarded as an instance of "retrograde development."

The most familiar of the Tubicola are the *Serpulæ* (fig. 171, *a*), the contorted and winding calcareous tubes of which must be known to almost every one as occurring on shells or stones on the sea-shore. One of the cephalic cirrhi in *Serpula* is much developed, and carries at its extremity a conical plug, or operculum, whereby the mouth of the tube is closed when the animal is retracted within it. In *Spirorbis* (fig. 171, *b*) the shelly

tube is coiled into a flat spiral, one side of which is fixed to some solid object. It is of extremely common occurrence on the fronds of sea-weed and on other submarine objects.

Equally familiar with *Serpula* is *Terebella*, the animal of which is in-

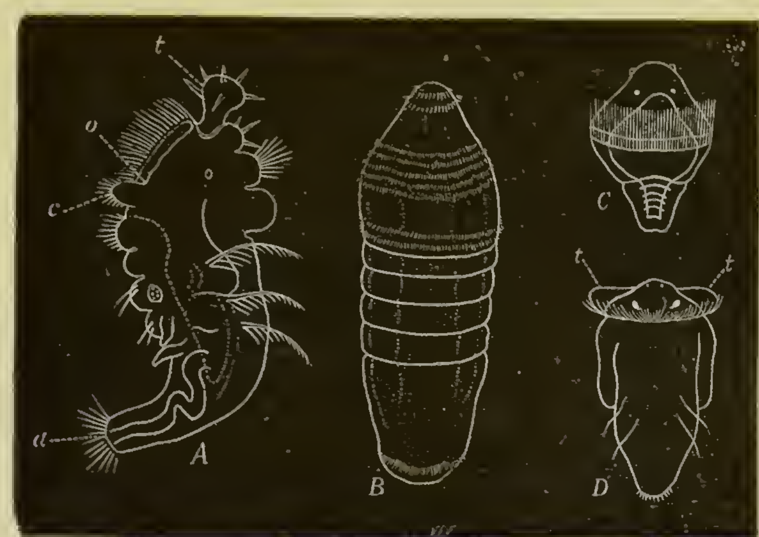

Fig. 172.—Development of Tubicolar and Errant Annelides. A, Larva of *Terebella*: *o* Position of the mouth; *a* Anus, surrounded by the posterior circlet of cilia; *c* Anterior circlet of cilia; *t* Tentacle. B, Polytrochal larva of *Arenicola*. C, Larva of *Phyllodoce*. D, Larva of *Spirorbis*; *t t* Tentacles. All the figures are greatly magnified. (After Claparède, Schultze, and A. Agassiz.).

cluded in a tube composed of sand and fragments of shell, cemented together by a glutinous secretion. In the *Sabellidæ* the tube is composed of granules of sand or mud. In *Pectinaria* the tube is free, membranous, or papyraceous, covered with sand-grains, and in the form of a reversed cone of considerable length.

As regards their *distribution in time*, Tubicolar Annelides are of common occurrence as fossils, various types (*Spirorbis*, *Cornulites*, *Ortonia*, *Conchicolites*, &c.) occurring in rocks as old as the Ordovician or Silurian.

SUB-ORDER II. ERRANTIA.—This division includes Polychætous Annelides, which are devoid of investing tubes, and enjoy a free and wandering life. In rare cases they are parasitic. The parapodia, in accordance with the animal's free habit of life, are more completely developed than in the *Tubicola*; and the gills, when present, are arranged on the sides of the body, on its dorsal aspect, sometimes in the middle region of the body only, or sometimes along almost the entire length. For this reason, the *Errantia* are sometimes spoken of as the "Notobranchiate" Annelides.

The sexes in the *Errantia* are in different individuals, and reproduction is usually sexual, though in some cases gemmation is known to occur. The process of gemmation is carried on by a single segment, and so long as it continues, the budding individual remains sexually immature, though

the young thus produced develop generative organs. Thus, there is in these cases a kind of alternation of generations, or rather an alternation of generation and gemmation ; the oviparous individuals producing eggs from

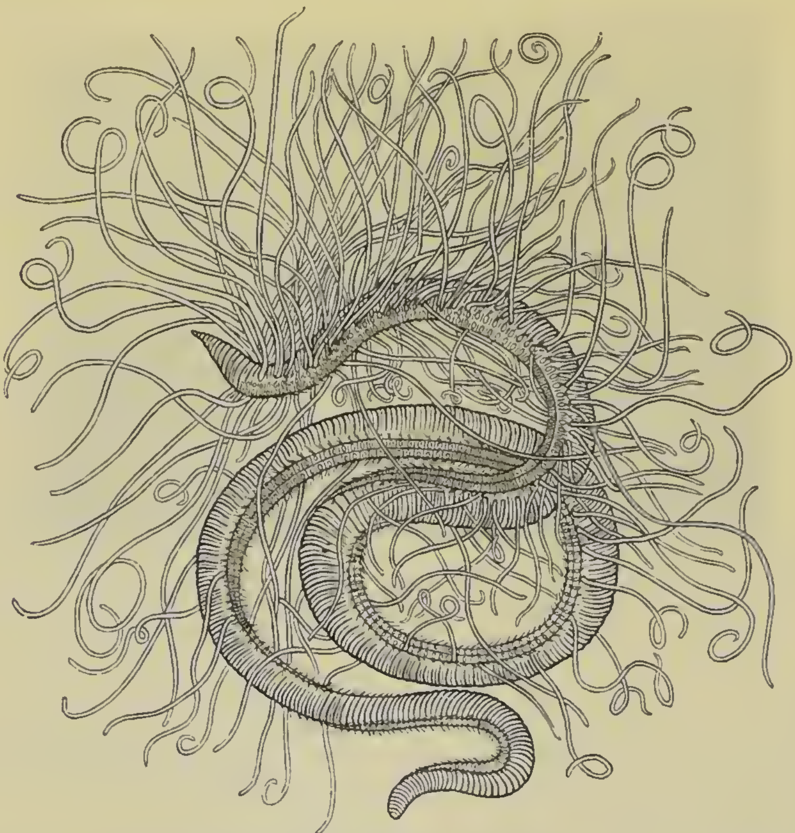

Fig. 173.—*Cirrhatulus grandis*, an "Errant Annelide," in its living condition. (After Verrill.)

which the gemmiparous individuals are born ; these, in their turn, but by a non-sexual process, producing the oviparous individuals. While the form of gemmation just alluded to has long been known as not uncommonly taking place among the Errant Annelides, no example of *continuous* gemmation has until lately been recognised in any Annelide. Recently, however, Dr M'Intosh has described a remarkable species of *Syllis* (*S. ramosa*), which inhabits a Hexactinellid Sponge from the Philippines, and in which the thread-like body is intricately branched, giving off lateral offsets, and thus becoming a truly composite organism. This singular form is further remarkable in the fact that no traces of a *head* have hitherto been discovered, so that it is probable that the entire branched organism possessed but a single head.

Not only does gemmation occur among the Errant Annelides, but, in a few instances, fission has been noticed to take place. Occasionally, also, the males and females differ from one another, and both may differ from the sexless forms, when these exist. Thus, *Heteronereis* is founded upon the sexless forms of *Nereis;* whilst the species of the genus *Autolytus*, amongst the *Syllidea*, exhibit a still more remarkable polymorphism, the

males and females being extremely dissimilar, and there being in addition a third sexless form, which produces the sexual individuals by gemmation at its hinder extremity.

The embryo usually appears, on its liberation from the ovum, as a free-swimming, ciliated body, possessing a mouth, intestine, and anus. The cilia are primarily diffused, but become aggregated so as to form a single median belt, or two bands, one about each extremity, or a series of bands (fig. 172, B and C). The head, with its feelers and eye-specks, appears at one extremity, whilst the segments of the body begin to be formed at the other. Each segment is developed in four parts, the two principal ones forming half-rings, united by shorter side-pieces, from which the setigerous foot-tubercles are developed. The ciliated band or bands finally disappear, and new rings are rapidly added by intercalation between the head and the segments already formed.

All the Errant Annelides are marine, occurring in all seas from the Arctic Ocean to the equator, and extending to great depths. A few forms (*e.g.*, *Tomopteris*) are pelagic. Others live in sand and mud; whilst others hide under stones, or in fissures in rock-pools; and others, again, bore holes in calcareous rocks. A few live as "commensals" on other animals.

Of the commoner British types, the Lob-worm (*Arenicola piscatorum*) is found almost everywhere, burrowing in the sand of the sea-shore. It has tufted gills on the middle and hinder part of the body. In the Sea-mice (*Aphrodite* and *Polynoe*) there are broad chitinous scales ("elytra") on the dorsal surface of the body, covering the notopodia. In the Common Sea-mouse (*Aphrodite aculeata*), the thick bunches of setæ attached to the parapodia are brilliantly iridescent. The Sea-centipedes (*Nereidæ*) have long segmented bodies, with a very distinct head, carrying eyes and feelers, while the mouth usually has horny jaws.

As regards their *distribution in time*, the *Errantia* are recognised in the fossil condition by the tracks which they have left upon ancient sea-bottoms, or by their burrows in sand or mud, or, occasionally, by impressions formed by the body of the worm itself. Their presence in many ancient rocks is more satisfactorily established by the occurrence of their horny jaws, and from such remains it is known that they abounded in strata as old as the Ordovician, or even the Cambrian.

CLASS III. CHÆTOGNATHA (Leuckart).—*Elongated cylindrical animals having the hinder extremity of the body furnished with an integumentary fin. Anterior end of the body provided with setæ and corneous jaws. No foot-tubercles. Sexes united in the same individual.*

This class includes only the singular pelagic animals belonging to the genus *Sagitta*, the precise systematic position of which is somewhat doubtful. They appear, however, to form

a connecting link between the Annelides on the one hand, and the free Nematoids on the other hand.

The *Sagittæ* (fig. 174) have elongated transparent bodies, rarely over an inch in length, having the hinder end of the body expanded into a striated caudal fin, similar fins often existing on the sides of the body as well. The head carries a series of setæ placed in front of the mouth, and the oral aperture is furnished with unciform corneous bristles or "falces," which act as jaws. The alimentary canal is straight, and terminates in an anus placed at the base of the tail below.

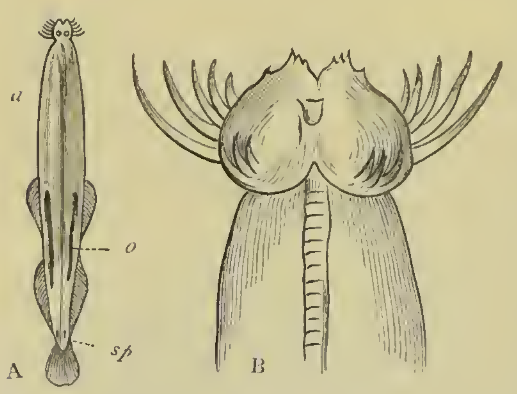

Fig. 174.—Morphology of *Chætognatha*. A, *Sagitta tricuspidata*, of the natural size: *o* One of the ovaries; *sp* Orifice of one of the male organs of reproduction. B, Head of the same, viewed from beneath and greatly enlarged, showing the horny, setiform jaws. (After Saville Kent.)

"A single oval ganglion lies in the abdomen, and sends, forwards and backwards, two pairs of lateral cords. The lateral cords unite in front of and above the mouth into a hexagonal ganglion. This gives off two branches which dilate at their extremities into the spheroidal ganglia, on which the darkly pigmented imperfect eyes rest. The ovaries, saccular organs, lie on each side of the intestine and open on either side of the vent; *receptacula seminis* are present. Behind the anus, the cavity of the tapering caudal part of the body is partitioned into two compartments; on the lateral parietes of these, cellular masses are developed which become detached, and, floating freely in the compartment, develop into spermatozoa. These escape by spout-like lateral ducts, the dilated bases of which perform the part of *vesiculæ seminales*. The embryos are not ciliated, and undergo no metamorphosis" (Huxley).

The species of *Sagitta* are found, living in the open sea, in the Mediterranean, and in the Atlantic and Pacific Oceans.

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CHAPTER XXVII.

ARTHROPODA. CRUSTACEA.

DIVISION II. ARTHROPODA, OR ARTICULATA.—The remaining members of the sub-kingdom *Annulosa* are distinguished by the possession of *jointed appendages, articulated to the body;* and they form the second primary division—often called by the name *Articulata*. As this name, however, has been employed in a wider sense than is understood by it here, it is best to adopt the more modern term *Arthropoda*.

The members of this division, comprising the *Crustacea* (Lobsters, Crabs, &c.), the *Arachnida* (Spiders and Scorpions), the *Myriopoda* (Centipedes), and the *Insecta*, are distinguished as follows:—

The body (fig. 175) is composed of a series of segments, arranged along a longitudinal axis; each segment or "somite," occasionally, and some almost always, being provided with articulated appendages. Both the segmented body and the articulated limbs are more or less completely protected by a chitinous exoskeleton, formed by a hardening of the cuticle. The appendages are hollow, and the muscles are prolonged into their interior. The nervous system, at any rate in the embryonic condition, consists typically of a double chain of ganglia, placed along the ventral surface of the body, united by longitudinal commissures, and traversed anteriorly by the œsophagus. The hæmal system, when differentiated, is placed dorsally, and consists of a contractile cavity, or heart, provided with valvular apertures, and communicating with a perivisceral cavity, con-

taining corpusculated blood. Respiration is effected by the general surface of the body, by gills, by pulmonary sacs, or by tubular involutions of the integument, termed "tracheæ." In

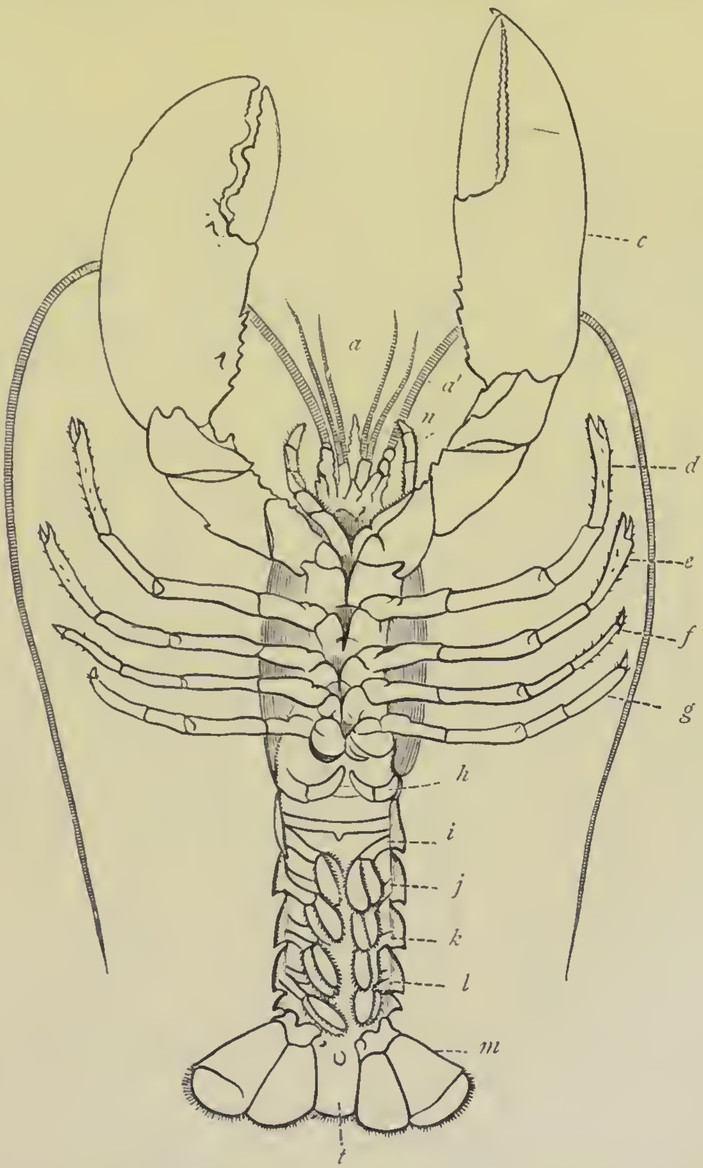

Fig. 175.—The common Lobster (*Homarus vulgaris*), viewed from below. *a* The lesser antennæ; *a'* The greater antennæ; *n* The last pair of foot-jaws; *c* The great claws, or first pair of legs; *d e f g* The last four pairs of walking legs; *h i j k l m* The six pairs of abdominal appendages, the last five being "swimmerets," and the last of all being greatly expanded; *t* The last segment of the body (telson), without appendages.

no member of the division are vibratile cilia known to be developed. According to Professor Huxley, an additional con-

stant character of the *Arthropoda* is to be found in the structure of the head, which is typically composed of six segments, and never contains less than four.

The *Arthropoda* are divided into four great classes—viz., the *Crustacea*, the *Arachnida*, the *Myriopoda*, and the *Insecta*.

Crustacea.

Class I. Crustacea.—The members of this class are commonly known as Crabs, Lobsters, Shrimps, King-crabs, Barnacles, Acorn-shells, &c. They are nearly allied to the succeeding order of the *Arachnida* (Spiders and Scorpions); but may usually be distinguished by the possession of articulated appendages upon the abdominal segments, by the possession of two pairs of antennæ, and by the presence of branchiæ.

The body is composed of a number of definite rings or segments ("somites"), each of which may be provided with a pair of jointed appendages. With rare exceptions, some of the somites of the adult always carry appendages; and one or more pairs are almost invariably adapted for mastication. The nervous system of the embryo has the typical Annulose form of a chain of ventral ganglia, between the first two pairs of which the gullet passes. No water-vascular system is present; but there is generally a true blood-vascular system. The heart, when present, is placed on the opposite side of the alimentary canal to the ventral nerve-chain, and communicates by valvular apertures with a surrounding venous sinus—the so-called "pericardium." When differentiated breathing-organs are present, these are always in the form of branchiæ or gills, adapted for respiring air dissolved in water.

In addition to these characters, the body in the *Crustacea* is always protected by a chitinous or sub-calcareous exoskeleton or "crust," and the number of pairs of articulated limbs is generally from five to seven. They all pass through a series of metamorphoses before attaining their adult condition, and every part that is found in an embryonic form, even though only temporarily developed, may be represented in a permanent condition, in some member of a lower order.

As regards the classification of the Crustacea, the tabular view which follows embodies the arrangement which is most generally adopted, and the diagnostic characters of each order will be briefly given, a more detailed description being reserved for the more important divisions of the class. Before proceeding further, however, it will be as well to give a description of

the morphology of a typical *Crustacean*, selecting the Lobster as being as good an example as any.

The body of a typical *Crustacean* (fig. 175) may be divided into three regions—a *head*, a *thorax*, and an *abdomen*—each of which is composed of a certain number of somites, though opinions differ both as to the number of segments in each region, and as to their number collectively. By the majority of authorities the body is looked upon as being typically composed of *twenty-one* segments, of which seven belong to the head, seven to the thorax, and seven to the abdomen. In many *Crustacea*, however, the segments of the head and thorax are welded together into a single mass, called the "cephalothorax"; in which case the body shows only two distinct divisions, of which the cephalothorax claims fourteen segments, whilst the remaining seven are allotted to the abdomen. Some authorities regard the terminal joint of the abdomen (the "telson") as an unpaired appendage, and not as a true somite; and on this view there are only *twenty* segments in the body of a typical Crustacean. Professor Huxley, further, differs from the above-mentioned view in the allotment of the somites, and divides the body into six cephalic, eight thoracic, and six abdominal somites.*

In no single example can a general view be obtained of the different segments and their appendages in the *Crustacea*. "Indeed the only segment that may be said to be persistent is that which supports the mandibles, for the eyes may be wanting, and the antennæ, though less liable to changes than the remaining appendages, are nevertheless subject to very extraordinary modifications, and have to perform functions equally various. Being essentially and typically organs of touch, hearing, and perhaps of smell, in the highest Decapods, they become converted into burrowing organs in the *Scyllaridæ*, organs of prehension in the *Merostomata*, claspers for the male in the *Cyclopoidea*, and organs of attachment in the *Cirripedia*. Not to multiply instances, we have presented to us in the *Crustacea* probably the best zoological illustration of a class, constructed on a common type, retaining its general characteristics, but capable of endless modification of its parts, so as to suit the extreme requirements of every separate species"—(H. Woodward).

* In reality the five hindmost segments of the eight somites here allotted to the thorax, should alone be regarded as constituting the *abdomen* proper, —that is, the region corresponding to the "abdomen" of insects and Arachnida. The six somites allotted above to the *abdomen* belong to what is strictly called the "*post-abdomen*" of the *Crustacea*.

Taking the common Lobster (figs. 175 and 176) as a good and readily obtainable type of the *Crustacea*, the body is at once seen to be composed of two parts, familiarly called the "head" and the "tail," the latter being jointed and flexible. The so-called "head" is really composed of both the head, properly so-called, and the thorax, which have coalesced so as to form a single mass, technically called the "cephalothorax." The so-called "tail," on the other hand, is truly the "abdomen." The various appendages of the animal are arranged along the lower surface of the body, and consist of the feelers, jaws, claws, legs, &c. The entire body, with the articulated appendages, is enclosed in a strong chitinous "shell," or exoskeleton, and the cephalothorax is covered by a great cephalic shield or plate, which is termed the "carapace."

Fig. 176.—Lobster with all the appendages except the terminal swimmerets removed, and the abdominal somites separated from one another. *r* "Rostrum"; *ca* Carapace, covering the cephalic and thoracic segments. 1 to 6, The first six segments of the abdomen. No. 6 carries the last pair of swimmerets. *t* Telson.

Each segment of the body may be regarded as essentially composed of a convex upper plate, termed the "tergum," which is closed below by a flatter plate called the "sternum," the line where the two unite being produced downwards and outwards, into a plate, which is called the "pleuron" or "pleura" (fig. 177).

Strictly speaking, the composition of the typical somite is considerably more complex, each of the primary arcs of the somite being really composed of four pieces. The tergal arc is composed of two central pieces, one on each side of the middle line of the body, united together and constituting the "tergum" proper. The superior arc is completed by two lateral pieces, one on each side of the tergum, which are termed the "epimera." In like manner the ventral or sternal arc is composed of a central plate, composed of two pieces united together in the middle line, and constituting the "sternum" proper; the arc being completed by two lateral pieces, termed the "episterna." These plates are usually more or less completely anchylosed together, and the true structure of the somite in these cases is often shown by what are called "apodemata." These are septa which

proceed inwards from the internal surface of the somite, penetrating more or less deeply between the various organs enclosed by the ring, and always proceeding from the line of junction of the different pieces of the segment (fig. 178).

In must be borne in mind that though the so-called "head"—that is to say, the "cephalothorax"—of the Lobster is produced by an amalgamation of the various somites of the head and thorax, this is not the case with the great shield which covers this portion of the body. This shield—the so-called "cephalic buckler," or "carapace"—is not produced by the union of the tergal arcs of the various cephalic and thoracic segments, as would at first sight appear to be the case. On the contrary, the "carapace" in the higher *Crustacea* is produced by an enormous development of the tergal pieces, or of the "epimera" or one or two of the cephalic segments: the tergal arcs of the remaining somites being overlapped by the carapace and remaining undeveloped.

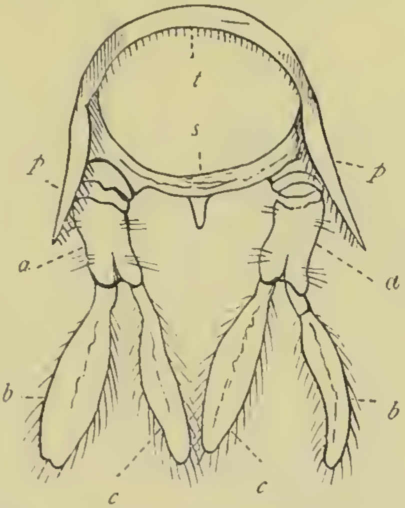

Fig. 177.—The third abdominal somite of the Lobster, separated. *t* Tergum; *s* Sternum; *p* Pleura; *a* Protopodite of the appendage; *b* Exopodite; *c* Endopodite.

.Each segment of the body of the Lobster, with the exception of the "telson," carries a pair of appendages, each of which consists typically of an undivided basal portion, or "protopodite" (fig. 177, *a*), and of two diverging branches attached to this. The outer of these branches is termed the "exopodite" (fig. 177, *b*), and the inner is termed the "endopodite"; but one or other, or both, of these terminal divisions of the appendage may be suppressed.

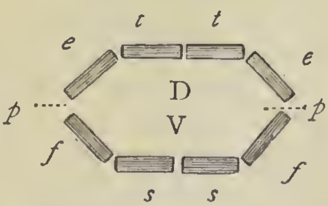

Fig. 178.—Theoretical figure illustrating the composition of the tegumentary skeleton of the Crustacea (after Milne-Edwards). D, Dorsal arc: *t t* Tergal pieces; *e e* Epimeral pieces. V, Ventral arc: *s s* Sternal pieces; *f f* Episternal pieces; *p p* Insertion of the extremities.

The carapace of the Lobster (fig. 176, *ca*) is prolonged in front into a pointed beak or "rostrum" (*r*), which overhangs the eyes. About the middle of the carapace is a transverse furrow (the "cervical groove"), which marks the boundary between the head and thorax. Extending backwards from the cervical groove are two short parallel minor furrows (the "branchio-cardiac grooves"), which indicate the line of division between the pericardial and branchial chambers. Immediately under the central region of the carapace, included

between these two grooves, lies the heart, while to the right and left of this region lie the gill-chambers, formed by a downward bending or reduplicature of the carapace on each side.

As regards the appendages borne by the various somites of the Lobster, the 1st segment carries the stalked eyes (fig. 179, A). The eyes are "compound"—composed, that is to say, of a number of separate lens united together—and the peduncle upon which they are carried may be regarded as representing the protopodite of the typical appendage.

The 2d segment carries a pair of small jointed appendages termed the "lesser antennæ" or "antennules." Each "antennule" (fig. 179, D) consists of a protopodite, and of a long transversely-jointed exopodite and endopodite. The upper flat face of the protopodite shows an oval slit (fig. 179, D, *i*), the outer lip of which is furnished with a line of long bristles. This is the auditory opening, and leads into a sac filled with fluid, on the hind wall of which are long "auditory setæ," which contain filaments from the auditory nerve, and have their apices embedded in a gelatinous mass containing siliceous particles.

The 3d segment carries the long "antennæ" (fig. 179, E), each of which consists of a short two-jointed protopodite, carrying a very long many-jointed endopodite and a rudimentary exopodite in the form of a flat scale. On the ventral face of the basal joint of the protopodite is a prominent conical tubercle, at which opens the duct of the "antennary gland" or "green gland." The organ so called is situated within the head, and consists of a glandular and a saccular portion; and it is usually regarded as representing a kidney.

The 4th segment carries the large and powerful jaws termed the "mandibles." Each of these (fig. 179, F) consists of a strong protopodite with a toothed inner edge, without an exopodite, but having the endopodite represented by a short three-jointed appendage, the "mandibular palp." Between the bases of the mandibles is the aperture of the mouth, bounded in front by an undivided chitinous plate—the upper lip or "labrum" (fig. 179, B)—and behind by a forked lower lip or "metastoma" (C).

The 5th segment carries another pair of jaws, known as the first pair of "maxillæ." Each of these (fig. 179, G) consists of a bifid protopodite and a minute unjointed endopodite, no exopodite being developed.

The 6th segment carries the second pair of "maxillæ," each of which (fig. 179, H) consists of a quadrifid protopodite, without an exopodite, but having a small undivided endopodite.

Attached to the outer side of the base of each of the second

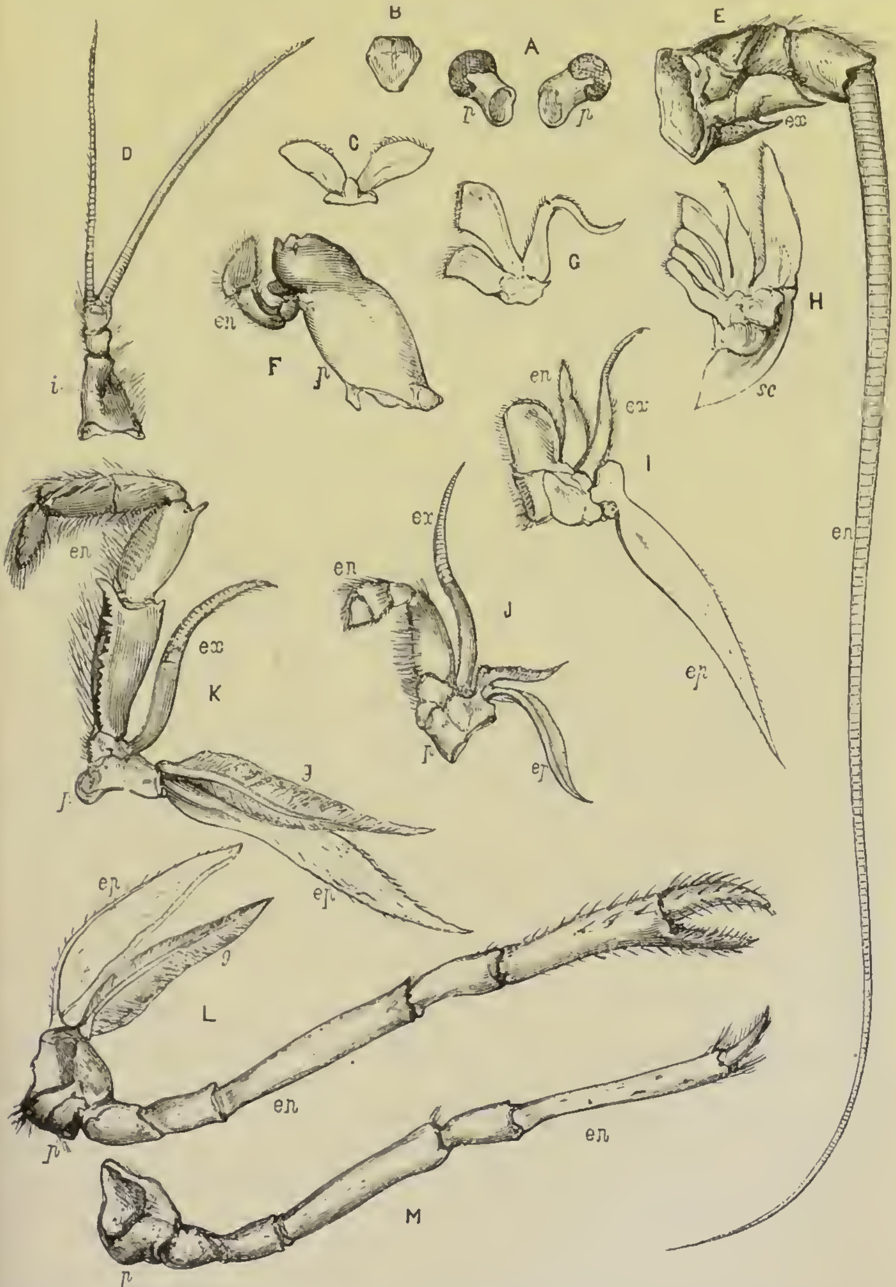

Fig. 179.—Appendages of the Lobster. A, The stalked eyes; B, Labrum; C, Metastoma; D, Antennule; E, Antenna; F, Mandible; G, First maxilla; H, Second maxilla; I, First maxillipede; J, Second maxillipede; K, Third maxillipede; L, Second walking leg; M, Fifth walking leg; *p* Protopodite; *en* Endopodite; *ex* Exopodite; *ep* Epipodite; *sc* Scaphognathite; *g* Branchia; *i* Opening of auditory sac.

maxillæ is a long, flexible, spoon-shaped, horny plate, termed the

"scaphognathite" (*sc*). This lies in the anterior opening of the gill-chamber on each side, and its function is to cause a current of water to traverse the branchial cavity by constantly bailing water out of it. The "scaphognathite" represents the "epipodite" of the succeeding appendages.

The 7th segment (the last somite of the head) carries the first of three pairs of organs which are known as the "maxillipedes" or "foot-jaws," as they are intermediate in their structure between the jaws and the walking legs. Each of the first maxillipedes (fig. 179, I) consists of a lamellar protopodite, with a thin internal edge adapted for cutting, a short two-jointed endopodite, and a long exopodite (or "palp"). Its outer edge also bears a long pointed membranous plate, which is termed an "epipodite." No branchia is attached to this pair of maxillipedes.

The 8th segment (the first of the thorax) carries the second pair of maxillipedes (fig. 179, J), each of which consists of a protopodite, a jointed endopodite, and a slender exopodite or "palp." Externally, each carries also a membranous "epipodite" (*ep*), to the root of which is attached a minute branchial plume.

The 9th segment carries the third pair of maxillipedes, in many respects the most characteristic of all the appendages of the Lobster. Each of these (fig. 179, K) consists of a protopodite continued with apparent directness into a large leg-like endopodite, the inner edge of the basal joint of which is serrated and toothed, so as to serve by application to its fellow on the other side as a cutting organ. The exopodite is in the form of a slender "palp," and the base of the appendages carries a membranous "epipodite" and a large branchial plume.

The 10th, 11th, 12th, 13th, and 14th segments carry the five pairs of ambulatory legs, which are characteristic of the higher Crustaceans. The first pair of these are of very large size, and terminate in a pair of powerful pincers, constituting the great claws or "chelæ." The next two pairs are much more slender, and terminate in small and weak pincers or "chelæ." The last two pairs are also slender, but instead of being chelate, they terminate in simply pointed extremities (fig. 179, M). All the walking legs, except the last pair, have an "epipodite" and a plumose branchia attached to their bases (fig. 179, L).

The 15th segment (the first somite of the abdomen) carries a pair of singular appendages, of different form in the two sexes. In the male Lobster these organs (the "claspers")

consist of a protopodite, with a curiously folded endopodite, like a grooved spine. In the females these organs have a narrow membranous endopodite, and are soft.

The 16th, 17th, 18th, and 19th segments carry each a pair of small "swimmerets." Each of these consists of a protopodite carrying a paddle-like flexible endopodite and exopodite, the sides of which are fringed with hairs (fig. 177). These are used in swimming, and also serve to carry the ova in the females. The 20th segment carries also a pair of "swimmerets," but in this case (fig. 176, 6) the endopodite and exopodite are greatly widened out, and the exopodite is divided into two by a transverse joint.

The last or 21st segment of the body is the so-called "telson," and is devoid of appendages. On its under side is the opening of the anus.

As regards the internal anatomy of the Lobster, the mouth opens into a short and wide gullet which passes almost directly into a large globular stomach, occupying the greater part of the cavity of the head in front of the heart. The stomach is divided by a constriction into a wide cardiac division, which contains a complicated apparatus of "gastric teeth" (vulgarly called "the lady in the lobster"), and a smaller pyloric division. The latter opens into a slender thin-walled intestine, which is continued backward to the anal opening at the base of the telson, with hardly any change in its diameter. There is a large bilobed liver, the ducts of which open into the intestine just behind the pylorus.

The heart (fig. 180, *h*) is a large hexagonal muscular sac, placed dorsally, just behind the "cervical groove" of the carapace, and contained within a large membranous blood sinus, known as the "pericardium" or "pericardial sinus." The blood contained in the pericardium is derived from the gills, and is therefore arterial, and it is admitted to the heart by means of three pairs of valvular slits in the walls of the latter. The heart is thus systemic in function, and it distributes the aerated blood throughout the body by means of six large arterial trunks. The arteries end in capillaries which open into a series of venous sinuses, from which the blood is ultimately collected into a principal ventral sinus. Thence the blood passes to the branchiæ in which it is oxygenated, and from these organs, lastly, it is returned to the "pericardium," and thus enters the heart again.

The respiratory organs of the Lobster consist of twenty branchiæ on each side of the body, contained in a long narrow branchial chamber on each side of the cephalothorax, and

covered externally by the down-bent lateral prolongation ("branchiostegite") of the carapace. The branchial chambers are thus entirely outside the body, and are open behind, in

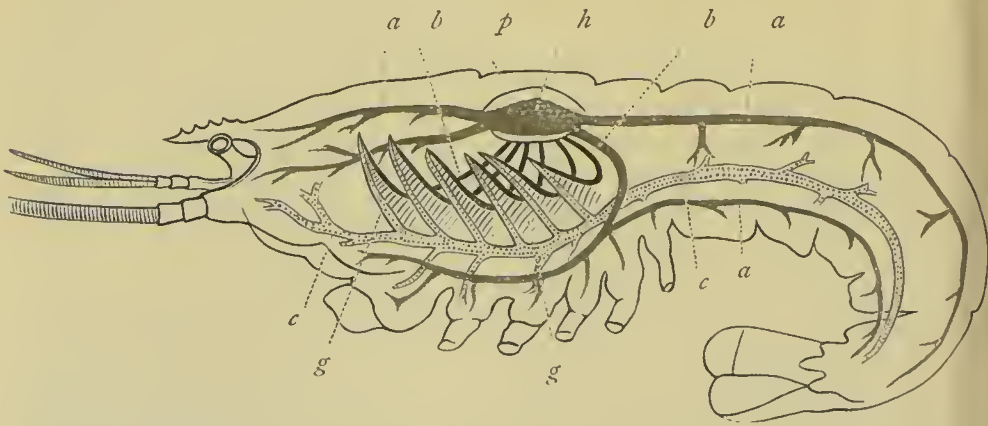

Fig. 180.—Diagram of the circulation of the Lobster. The systemic arteries are shaded longitudinally, the veins are dotted, and the branchial vessels are black. *h* Heart; *a a* Systemic arteries; *b b* Branchial vessels; *c c* Venous sinuses; *g g* Branchiæ; *p* Pericardium.

front, and below. Each branchia consists of a central stem carrying lateral vascular filaments on each side in a plumose manner. Six of the branchiæ are attached to the bases of certain of the appendages—viz., the 2d and 3d maxillipedes and the first four pairs of ambulatory legs. Another series of branchiæ are attached to the membrane connecting the bases of these limbs with the thorax; and four branchiæ are attached to the sides of the thorax itself. From the mode of attachment of the branchiæ, they necessarily participate in the movements of the basal joints of the limbs, thus assisting in causing a flow of water through the branchial chamber, the direction of the current being from behind forwards. The membranous "epipodites" serve to keep each gill separate from its neighbours. Moreover, though cilia are absent, a current of water is kept up by the rapid to-and-fro movement of the "scaphognathite" or spoon-like appendage of the 2d maxillæ, which vibrates in the anterior opening of the gill-chamber, just at the point where the cervical groove reaches the lower margin of the carapace.

The sexes of the Lobster, as in the Crustacea generally, are in different individuals. The ovaries constitute at the breeding season, large dark-coloured trefoil-shaped organs, united with one another, lying beneath the heart, and opening by short oviducts on the bases of the 3d pair of walking legs.

The testes have essentially the shape and position of the ovaries, but give origin to long white coiled efferent ducts (vasa deferentia), the openings of which are placed on the bases of the 5th pair of walking legs. The spermatozoa are aggregated into "spermatophores," and the ova, after expulsion from the oviducts, are carried about by the female attached in bunches to the swimmerets, in which position impregnation is effected. The young pass through a metamorphosis, though not of a very conspicuous nature, the larva having at first sessile eyes, without abdominal appendages, and with rudimentary thoracic limbs.

Lastly, the nervous system of the Lobster consists of a ventral nerve-cord carrying closely approximated double ganglia. The first or cerebral ganglion is supra-œsophageal, and gives off nerves to the eyes, antennules, and antennæ. Six bilobed thoracic ganglia are present, united by double commissures, the first commissure surrounding the gullet, and forming an œsophageal nerve-collar. There are also six bilobed abdominal ganglia, similarly united by double commissures.

As regards their classification, the *Crustacea* may be divided into the two primary sections of the *Entomostraca* and the *Malacostraca*. The first of these includes a great number of comparatively simple Crustaceans, in which the number of the segments and appendages is very various, sometimes rising above the normal, and sometimes falling below it. The second division includes the more highly organised Crustaceans, in which the number of the segments and appendages is definite. The Cirripedes (with the *Rhizocephala*) may be provisionally regarded as a third division under the name of *Anchoracephala*, characterised by the fact that the adult is attached to foreign bodies by the metamorphosed head. The orders included in these three divisions are shown in the following table :—

SUB-CLASS I. ANCHORACEPHALA.
Order 1. *Cirripedia*.

SUB-CLASS II. ENTOMOSTRACA.

Order 1.	*Ostracoda.*	*Legion*, Lophyropoda.
" 2.	*Copepoda.*	
" 3.	*Cladocera.*	*Legion*, Branchiopoda.
" 4.	*Phyllopoda.*	
" 5.	*Trilobita.*	
" 6.	*Xiphosura.*	*Legion*, Merostomata.
" 7.	*Eurypterida.*	

SUB-CLASS III. MALACOSTRACA.
Division A. HEDRIOPHTHALMATA.
Order 1. *Amphipoda.*
" 2. *Isopoda.*

Division B. PODOPHTHALMATA.
Order 1. *Stomatopoda.*
" 2. *Schizopoda.*
" 3. *Decapoda.*

CHAPTER XXVIII.

SUB-CLASS ANCHORACEPHALA.

THE members of this sub-class are Crustaceans which in the adult state (except the males of some forms) are destitute of the power of locomotion, being fixed by the metamorphosed head to the exterior of other animals or to foreign bodies. The young are locomotive, and are provided with eyes and antennæ. Branchiæ are wanting or rudimentary. The sexes are united in the same individual, with few exceptions.

ORDER CIRRIPEDIA.—*Adult attached, enclosed in an integumentary sac* ("*mantle-sac*") *within which a many-valved shell is typically developed. Antennæ modified for adhesion. Abdomen rudimentary. Limbs usually present, in the form of six pairs of multiarticulate cirri. Sexes generally united. Young locomotive.*

This sub-class includes, amongst others, the common Acorn-shells and the Barnacles or Goose-mussels. The typical *Cirripedia* are distinguished by the fact, that in the adult condition they are permanently fixed to some solid object by the anterior extremity of the greatly metamorphosed head; the first three cephalic segments being much developed, and enclosing the rest of the body. The larva is free and locomotive, and the subsequent attachment, and conversion into the fixed adult, is effected by means of a peculiar secretion, or cement, which is discharged through the antennæ of the larva, and is produced by special cement-glands. In the *Cirripedia*, therefore, the head of the adult is permanently fixed to some solid object, and the visceral cavity is protected by an articulated calcareous shell, or by a coriaceous envelope. The posterior extremity of the animal is free, and can be protruded at will through the orifice of the shell. This extremity consists

of the rudimentary abdomen, and of six pairs of forked, cirrated limbs, fringed with hairs, which are attached to the thorax, and serve to provide the animal with food. The two

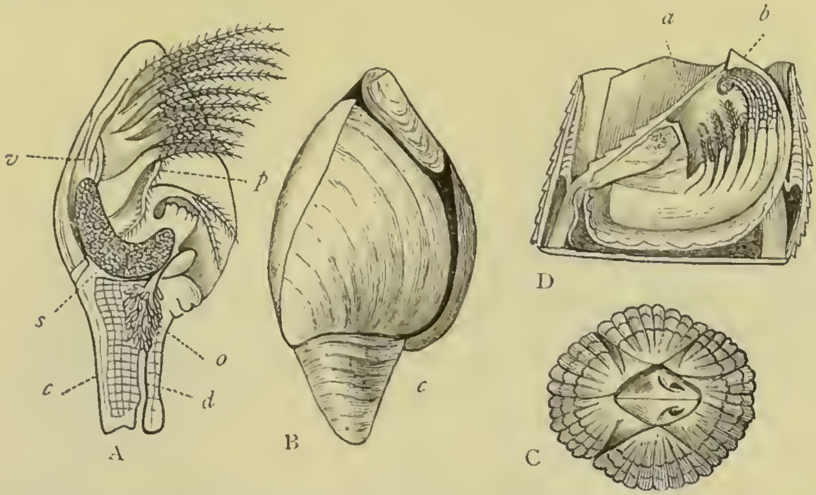

Fig. 181.—Morphology of Cirripedia. A, *Lepas pectinata*, one of the Barnacles, one side of the shell being removed, enlarged four times: *c* Peduncle; *d* Cement-duct; *o* Ovary; *s* Ovisac; *v* Vas deferens; *p* Penis. B, *Pæcilasma fissa*, enlarged five times: *c* Peduncle. C, *Balanus balanoides*, viewed from above, of the natural size. D, *Balanus tintinnabulum*, with the shell on one side removed to show the animal: *a* One of the valves ("scutum") of the operculum; *b* Another valve ("tergum") of the operculum. (After Darwin and Pagenstecher.)

more important types of the *Cirripedia* are the Acorn-shells (*Balanidæ*) and the Barnacles (*Lepadidæ*). In the former the animal is sessile, the larval antennæ, through which the cement exudes, being embedded in the centre of the membranous or calcareous "basis" of the shell. In the latter the animal is stalked, and consists of a "peduncle" and a "capitulum." The peduncle consists of the anterior extremity of the body, with the larval antennæ, usually cemented to some foreign body. The capitulum is supported upon the peduncle, and consists of a case composed of several calcareous plates, united by a membrane, enclosing the remainder of the animal.

The group of the *Rhizocephala* differs in many respects from that of the typical Cirripedes, cement-glands being absent, and the animal being fixed by means of branched root-like processes derived from the metamorphosis of the antennæ, while the alimentary canal and limbs are absent.

As regards the development of the typical *Cirripedia*, the larva has the form of a "Nauplius" (fig. 182, A), with an unsegmented, pyriform body, a median eye, and a dorsal carapace. During its life as a Nauplius, the young moults several times (seven times in *Lepas fascicularis*, which is here taken as exemplifying the development of the Cirripedia in general); and

these various castings of its integuments are accompanied with material changes of form. When fully grown, the Nauplius has an oval or pyriform body, enclosed in a carapace provided with long caudal and dorsal spines. There are three pairs of limbs, of which the first pair (representing the antennæ) are undivided, while the two hinder pairs (fig. 182) are bifid, and all carry natatory bristles. There is a very large labrum (fig. 182, *b*) placed

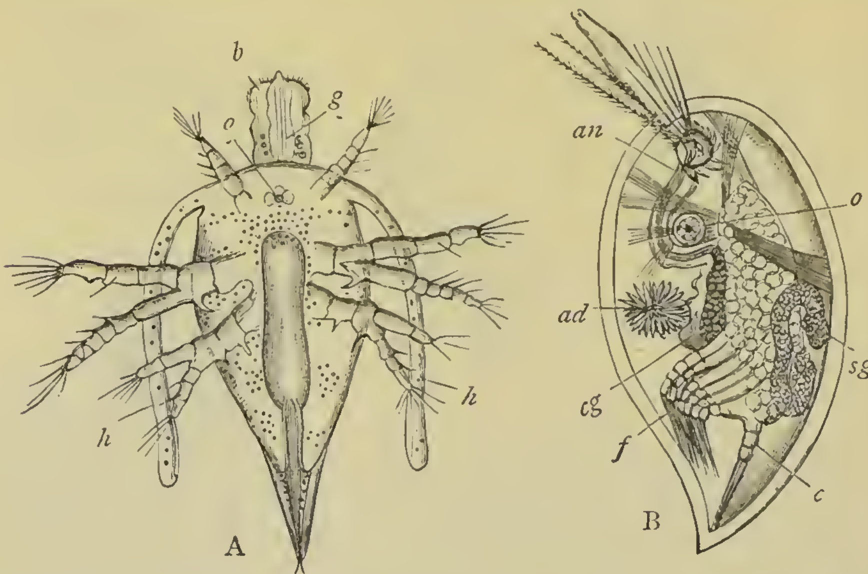

Fig. 182.—Development of *Lepas fascicularis*. A, Early stage of the Nauplius, showing the three pairs of appendages, of which the hinder two pairs are bifurcate: *o* Eye-spot; *b* Labrum; *g* Gullet; *h h* Lateral horns. B, The free-swimming Cypris-stage or "pupa," after the sixth moult, the antennæ and feet retracted within the shell: *an* Antenna, with its suctorial disc, traversed by the duct of the cement-gland (*cg*); *sg* Shell-gland; *o* Eye; *ad* Adductor-muscle; *f* Feet; *c* Caudal process. Both figures are greatly enlarged. (After Von Willemöes-Suhm.)

in front of the mouth, and there is a well-developed alimentary tube, which terminates by a distinct anus at the root of the caudal spine. There is at first merely a simple central eye; but in the adult Nauplius, two compound lateral eyes are developed in addition. Ultimately, the Nauplius passes into its second condition or "Cypris-stage" (fig. 182, B), when it is often spoken of as a "pupa." It is now enclosed in an oval, bivalved, mussel-shaped shell, with an opening along the ventral margin. The second and third pairs of the appendages of the Nauplius have now disappeared, and the first pair of appendages constitute strong four-jointed antennæ, the penultimate segment of which is disc-shaped, and is pierced centrally by a pore, which is the opening of the excretory duct of the "cement-glands," these organs being situated at the bases of the antennæ. The thorax has developed upon its sides six pairs of forked natatory limbs; and the abdomen is rudimentary, three-jointed, with terminal forked swimming-appendages. The pupa does not feed, but is nourished by means of an extensive accumulation of fatty matter, which had been stored up by the Nauplius in the cephalic and dorsal regions of the body; while the great labrum of the latter is now very much reduced in size.

After a brief natatory life, the pupa fixes itself by means of the disc-segments of the antennæ to some foreign body, such as a rock, a piece of drift-wood, the skin of a Cetacean, a Sponge, the carapace of a Turtle, or the

colony of an Oceanic Hydrozoön. The "cement-glands" secrete copiously an adhesive cement, which is poured forth through the central apertures of the antennal discs, and by means of which the animal is firmly and finally fastened down to the object to which it in the first place attached itself. The body now becomes enclosed in a multivalve calcareous "test," produced by a special shell-gland. The organs of the mouth become fully developed, and the lateral eyes of the locomotive pupa become rudimentary or disappear altogether. Lastly, the six pairs of natatory limbs of the Cypris-stage are replaced by the six forked and multisegmentate "cirri" of the adult; while the base of the abdomen carries the penis, in the form of a proboscidiform appendage.

The form of the adult, as already said, differs considerably, but the two most important types are those presented respectively by the Sessile and by the Pedunculated *Cirripedia*, which together form the group of the *Thoracica*. A second group is that of the *Rhizocephala*, the animals composing which differ in many important respects from the typical forms of the order. The so-called *Abdominalia* and *Apoda* are two small groups of Cirripedes comprising certain aberrant types.

SUB-ORDER I. THORACICA.—The Cirripedes of this sub-order are the well-known Acorn-shells and Barnacles, all of which have well-developed biramous limbs upon the thoracic region of the body. The animal may be attached by a stalk ("Pedunculate Cirripedes," or Lepadoids), or may be attached directly by the short larval antennæ ("Sessile Cirripedes," or Balanoids).

In the Sessile Cirripedes or *Balanidæ*, commonly known as Acorn-shells (fig. 181, C, D), the animal is protected by a calcareous shell, formed by calcifications within the walls of the first three cephalic segments. The animal is placed within the shell, head downwards, and is fixed to the centre of a shelly or membranous plate, which closes the lower aperture of the shell, and which is termed the "basis." The "basis" is fixed by its outer surface to some foreign object, and is sometimes compact, sometimes porous. Above the basis rises a limpet-shaped, conical, or cylindrical shell, which is open at the top, but is capable of being completely closed by a pyramidal lid or "operculum." Both the shell itself and the operculum are composed of calcareous plates usually differing from one another in shape, and distinguished by special names. Within the shell the animal is fixed, head downwards. The thoracic segments, six in number, bear six pairs of limbs, each of which consists of a jointed protopodite and a much-segmented exopodite and endopodite, both of which are bristled, and constitute the so-called "cirri," from which the name of the sub-class is derived. These twenty-four cirri—the "glass

hand" of the *Balanus*—are in incessant action, being protruded from the opening of the shell, and again retracted within it, constantly producing currents of water, and thus bringing food to the animal. Two folded lamellæ in the interior of the sac of *Balanus* have been regarded as branchial, but these are more largely developed in *Coronula*. The *Coronulæ* are attached parasitically to the skin of whales, and are found in both northern and southern seas. In the genus *Verruca* the shell is unsymmetrical, and the pieces of the operculum, though movable, are not furnished with a depressor muscle. The species of *Balanus* itself are almost wholly shallow-water forms, and have a cosmopolitan distribution, though the genus is, geologically speaking, quite a modern one. The earliest fossil types of the Balanoids appear in the Secondary rocks, and the family of the *Verrucidæ* is represented in the Chalk.

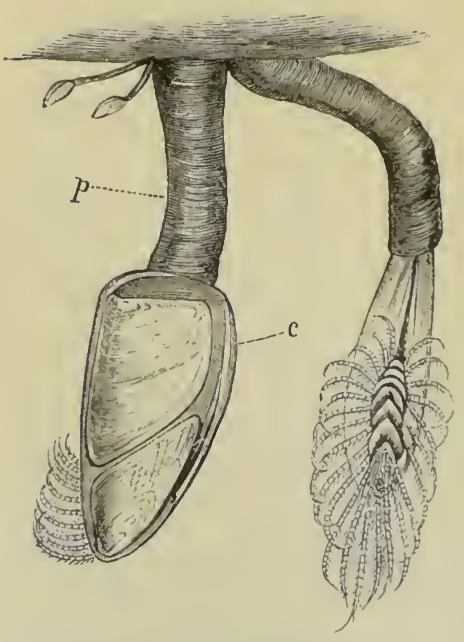

Fig. 183.—Two fully-grown individuals of the common Barnacle (*Lepas anatifera*), growing upon a foreign body. *p* The stalk of attachment; *c* The body of the animal enclosed in a shell, from which the legs can be protruded.

In the Pedunculate Cirripedes or "Lepadoids," the anterior extremity of the animal (figs. 183 and 181, A, B) is enormously elongated, forming with the prehensile antennæ, the cement-ducts, and their exudation, a long stalk or peduncle, whereby the animal is attached to some solid object. The peduncle is cylindrical, of varying length, flexible, and furnished with proper muscles. In some species it is naked, but in others it is furnished with calcareous scales. At its free extremity the peduncle bears the "capitulum," which corresponds to the shell of the Balanoids, and is composed of various calcareous plates, united together by a membrane, moved upon one another by appropriate muscles, and protecting in their interior the body of the animal with its appendages. The thorax and limbs resemble those of the *Balanus;* but "slender appendages, which from their position and connections are homologous with the branchiæ of the higher *Crustacea*, are attached to, or near to, the base

of a greater or less number of the thoracic feet, and extend in an opposite direction outside the visceral sac" (Owen).

All the *Balanidæ* are hermaphrodite, and this is also the case with most of the *Lepadidæ*, but some extraordinary exceptions occur in this latter order. Thus, in some species of *Scalpellum* the individual forming the ordinary shell is female, and each female has two males lodged in transverse depressions within the shell. These males "are very singular bodies; they are sac-formed, with four bead-like rudimental valves at their upper ends; they have a conspicuous internal eye; they are absolutely destitute of a mouth, or stomach, or anus; the cirri are rudimental and furnished with straight spines, serving apparently to protect the entrance of the sac; the whole animal is attached like the ordinary Cirripede, first by the prehensile antennæ, and afterwards by the cementing substance. The whole animal may be said to consist of one great sperm-receptacle, charged with spermatozoa; as soon as these are discharged, the animal dies."

"A far more singular fact remains to be told; *Scalpellum vulgare* is, like ordinary Cirripedes, hermaphrodite, but the male organs are somewhat less developed than is usual; and as if in compensation, several short-lived males are almost invariably attached to the occludent margin of both scuta. . . . I have called these beings *complemental males*, to signify that they are complemental to an hermaphrodite, and that they do not pair like ordinary males with simple females" (Darwin).

The Lepadoids usually attach themselves to floating objects in the sea, dead or alive. In *Anelasma*, the peduncle develops root-like processes, by which the animal is attached to the skin of sharks. The range of the Lepadoids in depth is very great, the genus *Scalpellum* occurring at depths of about 3000 fathoms. As regards their geological range, the earliest types appear in the Silurian rocks (*Turrilepas*), and the group appears to attain its maximum in the Cretaceous period.

SUB-ORDER 2. ABDOMINALIA. — This small group comprises certain aberrant Cirripedes (*Cryptophialus* and *Alcippe*), which have a flask-shaped mantle, without calcareous plates, with three pairs of cirri attached to the segments of the abdomen. The sexes are distinct, and the males are dwarfed, and are attached to the females, these latter boring into the shells of Molluscs.

SUB-ORDER 3. APODA.—This includes the single genus *Proteolepas*, in which the mantle-sac is rudimentary, the alimentary canal is degenerate, there are no limbs, and the mouth is adapted for suction. The sexes are united, and the animal lives as a parasite in the mantle of other Cirripedes.

SUB-ORDER 4. RHIZOCEPHALA.—The Cirripedes included in this section are devoid of segmentation, and have no limbs. The mouth and alimentary canal are wanting. The hermaphrodite adult is parasitic, and is attached to its host by ramified root-like processes, representing the metamorphosed

antennæ. The young is locomotive, and has the form of a "Nauplius."*

The *Rhizocephala* constitute a peculiar group of Crustaceans, the adults of which are found attached parasitically to the abdomen of Crabs and Hermit-crabs. The body (fig. 184, B)

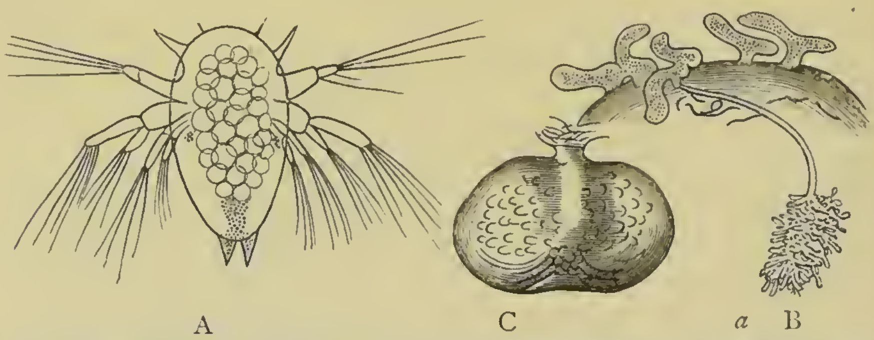

Fig. 184.—Morphology of *Rhizocephala*. A, First larval form of *Sacculina purpurea*, greatly enlarged. B, Young of *Peltogaster socialis* attached to the abdomen of a Hermit-crab; at *a* the root-like processes of attachment of one individual are shown. C, Body of *Sacculina carcini*, of the natural size: the roots of attachment not shown. (A and B are after Fritz Müller.)

is sac-like, and non-segmented, and consists of a muscular mantle in which no skeletal structures are developed, its only aperture being reproductive and closed by a sphincter. There are no limbs, sense-organs, or alimentary canal, but there are well-developed reproductive organs, each individual being hermaphrodite. The sac-like body is kept in connection with its host by means of branched, root-like processes of attachment (fig. 184, B), which sink deeply into the tissues of the latter, and represent the modified antennæ. By means of these hollow ramified processes, which wind round the viscera of its host, the animal is enabled to nourish itself.

The embryos of the *Rhizocephala* (fig. 184, A) are at first "naupliiform," with an ovate unsegmented body, an unpaired median eye, and a dorsal shield or carapace. The abdomen terminates in a movable caudal fork, and there is neither mouth nor alimentary canal. In their second stage (as so-called "pupæ"), the young of the *Rhizocephala* are enclosed in a bivalve shell, the foremost pair of limbs constitute peculiar organs of adhesion ("prehensile antennæ" of Darwin), the two following pairs of limbs are cast off, and six pairs of powerful biramous natatory feet are formed on the thorax.

* The name of "Nauplius" was given by O. F. Müller to the unsegmented ovate larva of the lower *Crustacea*, with a median frontal eye, but without a true carapace; and this name may be conveniently employed to designate all the larval forms which agree in these characters.

There is still no mouth. The "pupæ" now attach themselves to the abdomen of Crabs, *Porcellanæ*, and Hermit-crabs; they remain astomatous; "they lose all their limbs completely, and appear as sausage-like, sack-shaped, or discoidal excrescences of their host, filled with ova; from the point of attachment closed tubes, ramified like roots, sink into the interior of the host, twisting round its intestine, or becoming diffused amongst the sack-like tubes of its liver. The only manifestations of life which persist in these *non plus ultras* in the series of retrogressively metamorphosed Crustacea are powerful contractions of the roots, and an alternate expansion and contraction of the body, in consequence of which water flows into the brood-cavity, and is again expelled through a wide orifice."—(Fritz Müller).

CHAPTER XXIX.

SUB-CLASS ENTOMOSTRACA.

Sub-class II. Entomostraca (*Gnathopoda*, Woodward).—The division of the Entomostracous Crustaceans includes a large number of comparatively simple types, in which the limbs and segments are usually indefinite in number, the former either fewer or more than fourteen, and the character

Fig. 185.—Fresh-water Entomostraca. *a Cypris tris-striata*; *b Daphnia pulex*; *c Cyclops quadricornis*.

of the appendages is very varied. The limbs are principally developed in the cephalic region, and their bases generally act as jaws. The characteristic larval form is that of a "nau-

plius." The orders of the *Eurypterida* and *Xiphosura* (with the probable addition of the *Trilobita*), here placed among the *Entomostraca*, are grouped together by Professor Claus in a special section, which he terms *Gigantostraca*, and which he regards as probably related to the *Arachnida*.

The *Entomostraca* are divided into three great divisions, or "legions," the *Lophyropoda*, *Branchiopoda*, and *Merostomata*.

DIVISION A. LOPHYROPODA.—The members of this division possess few branchiæ, and these are attached to the appendages of the mouth. The feet are few in number, and mainly subserve locomotion; the carapace is in the form either of a shield protecting the cephalothorax, or of a bivalve shell enclosing the entire body. The mouth is mostly not suctorial, but is furnished with organs of mastication.

This division comprises the two orders *Ostracoda* and *Copepoda*.

ORDER I. OSTRACODA.—*Small Crustaceans having the entire body enclosed in a shell or carapace, which is composed of two valves united along the back by a membrane. There are seven pairs of appendages, of which the first two are antennæ, and the posterior appendages are adapted for creeping or swimming.*

The *Ostracoda* are all small Crustaceans in which the body is enclosed within a bean-shaped or mussel-shaped shell, composed of two valves united along the back by an elastic ligament (fig. 186, B). The animal can open the valves of the shell along their ventral margin, and can protrude the appendages and the caudal extremity of the abdomen. The first two pairs of appendages are antennules and antennæ (fig. 186, A), which can be used as locomotive limbs. These are followed by a pair of mandibles, succeeded by a pair of maxillæ; and the next two pairs of appendages may be either jaws or legs. The sixth and seventh pairs of appendages are leg-like, and variously formed in different cases. A median eye, or two lateral eyes are present. Branchial plates are attached to some of the jaws, and a distinct heart may be present (*Cypridina*) or absent (*Cypris* and *Cythere*). The young forms are usually "nauplii," but there may be no metamorphosis. Parthenogenesis is a not uncommon phenomenon in the Ostracodes.

The *Ostracoda*, often called "Water-fleas," are represented by very numerous forms both in fresh water and in the sea. The commonest fresh-water types are the little *Cyprides* (figs. 185, *a*, and 186, B). The marine Ostracodes (*Cythere*, *Cypridina*, &c.), are mostly shallow-water forms, and are of

small size; but there are deep-sea types which attain comparatively gigantic dimensions (nearly an inch in length). Numerous fossil forms of the Ostracodes are known, their

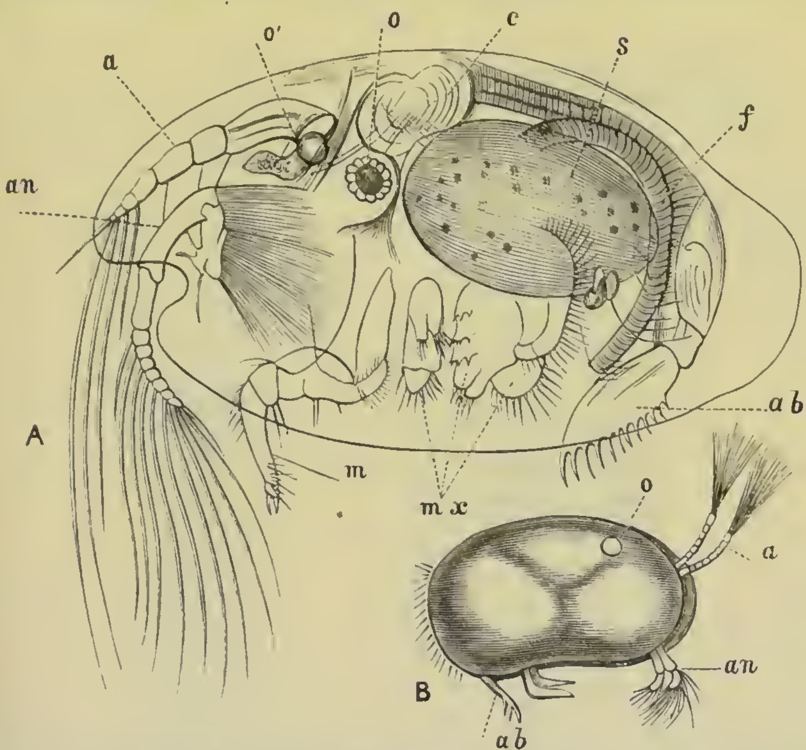

Fig. 186.—Ostracoda. A, *Cypridina Messinensis*, viewed from the side, and greatly enlarged, one half of the shell being removed; B, *Cypris fusca*, viewed from the side, and less highly magnified, the shell-valves being retained, but slightly displaced. *a* Antennules; *an* Antennæ; *o* Eye; *o'* Ocellus; *c* Heart; *s* Stomach; *f* Whip-like appendage for the retention of the brood; *ab*, Extremity of the abdomen; *m* Mandibular appendage; *m.x*, The first, second, and third maxillæ.

remains occurring in all formations, from the Cambrian onward.

ORDER II. COPEPODA.—*Small Crustaceans having bifid natatory feet, and the head and thorax usually covered with a carapace. Two caudal locomotive appendages are often present; but the abdomen does not carry limbs. Segmentation is distinct in the free forms; but it is more or less lost in the females of the parasitic types.* A distinct heart is sometimes absent (as in the *Cyclopidæ*); but is sometimes present. The young are mostly "nauplii," with unpaired eyes, three pairs of limbs (the future antennæ and mandibles), and two terminal setæ. Next, the maxillæ are produced, and usually three other pairs of limbs (the foot-jaws and the two front pairs of natatory feet). At the next moult, the larva assumes the *Cyclops* form, but it has at first fewer limbs and somites.

The typical *Copepoda* have the feet adapted for swimming (fig. 187, B), and have the mouth usually fitted for mastication, while the segmentation of the body is distinct. They are for

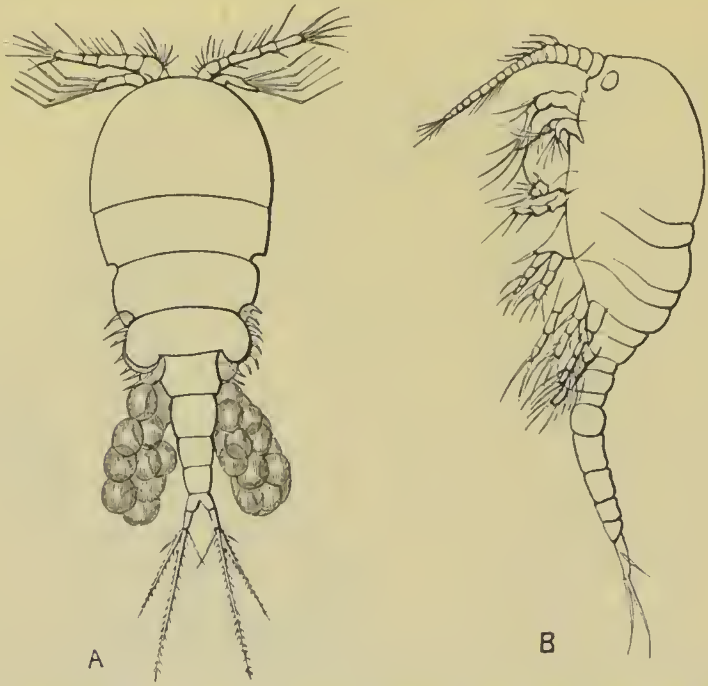

Fig. 187.—Copepoda. A, Female of *Cyclops æquoreus*, seen from above, and greatly enlarged, with the external ovisacs. B, Female of *Cyclopina littoralis*, viewed from one side, and greatly enlarged. (After G. S. Brady.)

the most part free-swimming locomotive animals, and are found abundantly in both fresh and salt water. Amongst the commonest forms are the species of *Cyclops* (fig. 185, *c*, and fig. 187, A) in which the front of the body is covered by a head-shield, and there is a long segmented abdomen. A simple unpaired eye is present, and the antennæ of the males are employed as organs of prehension. The female carries the eggs in a pair of external ovisacs, and the young are often produced parthenogenetically. The *Cyclopidæ* are almost entirely confined to fresh water. Among the marine types, the genus *Cetochilus* may specially be mentioned. The species of this genus sometimes occur in such vast numbers as to discolour the waters of the ocean; and they furnish an abundant supply of food to fishes and other inhabitants of the sea.

Various groups of the Copepods are parasitic in their habits, and these have often been classed together under the name of Fish-lice (*Ichthyophthira*). All these forms have the organs of the mouth adapted for piercing and suction. In some of these

parasitic types (such as *Caligus* and *Argulus*), the adults retain their natatory feet, and are thus not permanently attached to their hosts. The species of *Caligus* have a large shield-like cephalothorax, and attach themselves as parasites to the integument and gills of various sea-fishes. In *Argulus* the general form of the body is much as in *Caligus;* but the first pair of foot-jaws are converted into powerful suckers for adhesion. The species of *Argulus* attach themselves to various fresh-water fishes.

In other groups of parasitic Copepods, retrogressive de-

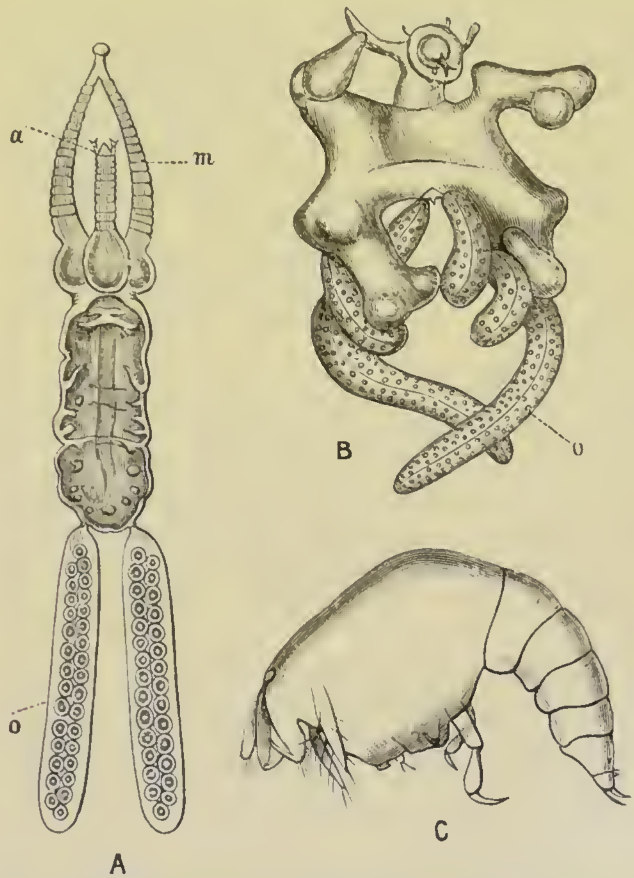

Fig. 188.—Parasitic Copepods (*Ichthyophthira*). A, Female of *Tracheliastes polycolpus*, enlarged about eight times (after Nordmann): *m* Second pair of maxillipedes, united at their extremities to form an adhesive disc; *a* Prehensile antennæ; *o* Ovisacs. B, Female of *Diocus gobinus*, enlarged four times: *o* Ovisacs. C, Pigmy male of the preceding, enlarged thirty-eight times. (After Steenstrup and Lütken.)

velopment takes place to a much more marked degree than in the types just spoken of. In the forms in question (*Lernæa*, *Achtheres*, *Peniculus*, *Tracheliastes*, &c.), the young have the form of free-swimming "nauplii," or of locomotive *Cyclops*-

like larvæ, in which condition they possess both organs of vision and natatory appendages. The future of these free larvæ varies with the sex of the individual. The adult females (fig. 188, A and B) are parasitic in habit, and become fixed to the skin, gills, or eyes of fishes, undergoing at the same time an extraordinary retrograde change. The organs of the mouth become adapted for suction, and some of the cephalic appendages are modified for purposes of adhesion. The locomotive limbs degenerate in size, or are wholly lost, and the eye may disappear. The abdomen is reduced in size, and the segmentation of the body is obscured or lost, the animal often becoming more or less swollen or deformed (fig. 188, B). Very commonly there are appended to the abdomen two external ovisacs (fig. 188, *o*) in which the eggs are contained. In some cases (*Lernæa*) this change does not take place until after impregnation has been effected. On the other hand, the males (fig. 188, C) are to a large extent exempt from the retrogressive metamorphosis by which the females are affected. They are usually dwarfed in size, and have the general form of such Copepods as *Cyclops;* and they either adhere to the females, or may even (as in *Lernæa*) retain their natatory feet, and live a free life.

Division B. Branchiopoda.—The Crustaceans included in this division have many branchiæ, and these are attached to the legs, which are often numerous, and are formed for swimming. In other cases the legs themselves are flattened out so as to form branchiæ. The body is either naked, or is protected by a carapace, which may enclose either the entire body, or the head and thorax only. The mouth is provided with organs of mastication.

The *Branchiopoda* comprise the *Cladocera*, the *Phyllopoda*, the *Phyllocarida*, and probably the *Trilobita*, though this last departs in many respects from the first three groups.

Order I. Cladocera.—The members of this order are *small Crustaceans, which have a distinct head, and have the whole of the remainder of the body enclosed within a bivalve carapace. The feet are few in number* (*usually four, five, or six pairs*), *and are mostly respiratory, carrying the branchiæ. Two pairs of antennæ are present, the larger pair being of large size, branched, and acting as natatory organs.* The *Cladocera* quit the egg with the full number of limbs proper to the adult. A distinct heart (fig. 189, *h*) is present, in the form of an ovate contractile sac. The *Cladocera* are exclusively confined to fresh water.

In the *Daphnia pulex* (fig. 185, *b*), or "Branched-horned

Water-flea," which occurs commonly in our ponds, the body is enclosed in a bivalve shell, which is not furnished with a hinge posteriorly, and which opens anteriorly for the protrusion

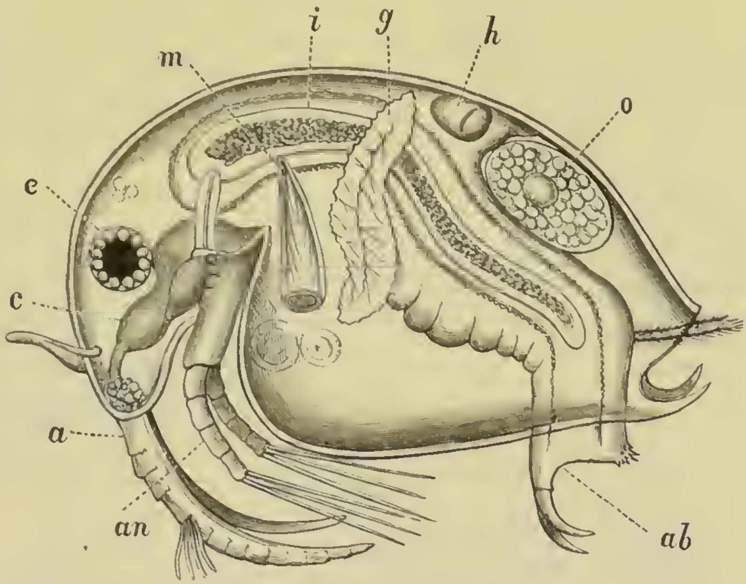

Fig. 189.—Cladocera. *Bosmina lævis*, greatly enlarged, the internal organs showing through the translucent shell: *a* Antennules; *an* Antennæ; *c* Cephalic ganglion, terminating in front in a mass of ganglion-cells at the base of the antennules; *e* Eye; *m* Mandible; *i* Alimentary canal; *g* Shell-gland; *h* Heart; *o* Ovum contained in the brood sac; *ab* Extremity of the abdomen, with terminal claw-like appendages. (After Leydig.)

of the feet. The head is distinct, not enclosed in the carapace, and carrying a single eye. The mouth is situated on the under surface of the head, and is provided with two mandibles and a pair of maxillæ. The gills are in the form of plates, attached to the five pairs of thoracic legs. The males are very few in number, compared with the females, and a single congress is all that is required to fertilise the female for life. Not only is this the case, but the young females produced from the original fecundated female are able to bring forth young without having access to a male. Two kinds of eggs occur in *Daphnia*. In the first of these, or "summer eggs," the ova (from ten to fifty in number) are deposited in an open space between the valves, and are retained there until the young are ready to be hatched. In the second of these, or "winter eggs," which alone are fecundated, the ova (generally two in number) are placed in a peculiar receptacle, which is formed on the back of the carapace, and is called the "ephippium" or saddle. The eggs remain dormant through the

winter, and are hatched in spring by the warmer temperature of the water.

ORDER II. PHYLLOPODA.—*Crustacea, mostly of small size, generally having the front part of the body protected by a shield-like carapace, or sometimes having the body enclosed in a bivalve shell. The feet are usually numerous, and more or fewer of them are leaf-like in form, and act as respiratory organs.* Parthenogenesis is common, and the young are hatched in the form of a "nauplius." All the recent Phyllopods (if *Nebalia* be excluded) are inhabitants of fresh water.

One of the most typical genera of the *Phyllopods* is *Apus* (fig. 191, B), in which the anterior part of the body is covered with an oval carapace, carrying a pair of compound eyes upon its upper surface in front. The under surface carries sixty pairs of feet, of which the first is divided into three slender whip-like branches on each side, while the remainder are foliaceous and branchial. *Apus* is gregarious, and is often found in great numbers in pools and ditches in Europe, allied forms occurring in North America. Closely related to *Apus* is the genus *Lepidurus* (fig. 190, A), which is also found in the United States.

In the genus *Limnadia* the body is enclosed in an oval, strongly bent,

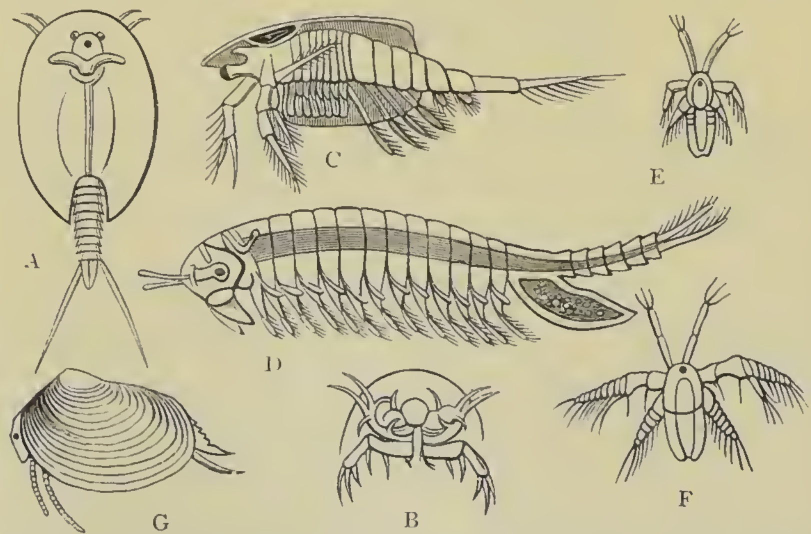

Fig. 190.—Morphology of Phyllopoda. A, *Lepidurus Angassi*, viewed dorsally. B, Under side of head of the same. C, *Nebalia bipes*, one side of the carapace being removed, so as to show the branchial feet. D, *Branchipus stagnalis*, female. E and F, Young stages of the same. G, A magnified specimen of *Estheria*, in its living state.

and very delicate carapace, and there are usually from eighteen to twenty-two pairs of leaf-like feet. In *Estheria* (fig. 190, G) the body is protected by a mussel-shaped, sub-ovate carapace, which is extremely like the shell of a Bivalve Mollusc, not only in shape and appearance, but also in having the valves joined at their beaks dorsally, and marked by concentric lines of growth. The species live in fresh or brackish water, and numerous fossil forms are known, beginning as early as the Devonian period.

In the "Fairy Shrimps" (*Branchipus* and *Cheirocephalus*, fig. 190, D), the body is without a carapace, there is a long and segmented abdomen, and there are usually eleven pairs of foliaceous feet. The natural position of the animal in swimming, as also in *Apus* and its allies, is back-downwards. The species are found in ponds and swamps in various parts of the world. Lastly, the species of *Artemia*, often called "Brine-shrimps," are found inhabiting the brine-pans in salt-works, or occur in salt lakes in both the Old and New Worlds. There is some reason for believing that *Artemia* is only a degraded form of *Branchipus*—to which it is morphologically nearly related—produced by increased salinity of the water in which the animal lives.

PHYLLOCARIDA.—It has been proposed by Packard to found under this name a special section of *Crustacea* for the reception of the singular marine genus *Nebalia* (fig. 191, A), which

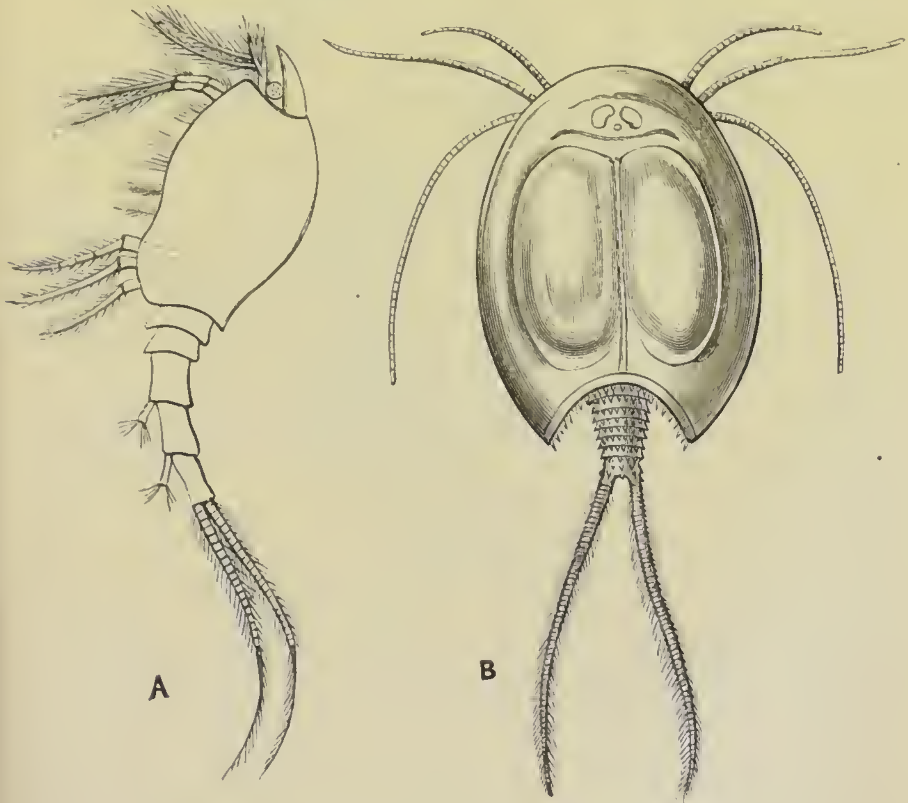

Fig. 191.—A, *Nebalia Herbstii*, enlarged about three times. B, *Apus cancriformis*, viewed from above.

is related on the one hand to the *Phyllopoda*, and on the other hand to the *Schizopoda*. The genus *Nebalia* includes small marine Crustaceans, in which the body is covered anteriorly with a bivalved carapace, produced in front into a beak or "rostrum," below which are placed two pedunculate eyes (fig.

190, C). There are two pairs of antennæ, and the jaws are followed by eight pairs of leaf-like thoracic feet, succeeded by a series of natatory feet, behind which are two pairs of small abdominal feet. In the vicinity of *Nebalia* must be placed many curious fossil Crustaceans (*Hymenocaris*, *Caryocaris*, *Dithyrocaris*, *Ceratiocaris*, &c.), many of which occur in very ancient fossiliferous formations.

ORDER III. TRILOBITA.—This order is entirely extinct, none of its members having survived the close of the Palæozoic period. The Trilobites are *Crustaceans in which the body is usually more or less distinctly trilobed; there is a cephalic shield, usually bearing a pair of sessile compound eyes; the thoracic somites are movable upon one another, and are very variable in number; the abdominal segments are coalescent, and form a caudal shield; there is a well-developed upper lip or "hypostome."*

As regards the general structure of the Trilobites, the body was protected by a well-developed shell or "crust," which covered the whole dorsal surface of the body, and which usually exhibits more or less markedly a division into three longitudinal lobes (fig. 192), from which the name of the order is derived. The crust is composed of a cephalic shield, generally crescentic in shape, a variable number of free and movable rings, constituting the thorax, and a caudal shield or "pygidium," the rings of which are more or less completely anchylosed. On the under surface of the head-shield in front, there is situated a forked or oval upper lip or "labrum," which resembles in form the labrum of the Phyllopodous genus *Apus*. Recent researches by Mr C. D. Walcott have also considerably increased our knowledge of the condition of the under surface of the body in the Trilobites. This observer, namely, has shown that the visceral cavity of the Trilobites (fig. 193, *b*) was bounded inferiorly by a thin membrane, which is attached to the lower margin of the dorsal crust all round. This ventral membrane was strengthened by calcified arches, which in turn supported the appendages beneath. As to these latter our knowledge is not yet complete, but we know that in some forms there existed a row of articulated appendages on each side of the middle line below. The thoracic appendages seem to have been slender five-jointed legs, in which the terminal segment forms a pointed claw, and the basal segment carries a jointed appendage, regarded by Mr Walcott as homologous with the "epipodite" of many recent Crustaceans. On each side of the thoracic cavity there is also attached a row of bifid spiral appendages (fig. 193, *e*), of the nature of gills; and branchial appendages were probably attached to the bases of the thoracic

limbs as well. With regard to the appendages of the head, the mouth is situated behind the hypostome, and is bounded by four pairs of jointed manducatory appendages, the basal joints of which are, partly or wholly, modified to act as jaws.

The cephalic shield of a typical Trilobite is more or less completely semicircular (fig. 192), and is composed of a central and of two lateral

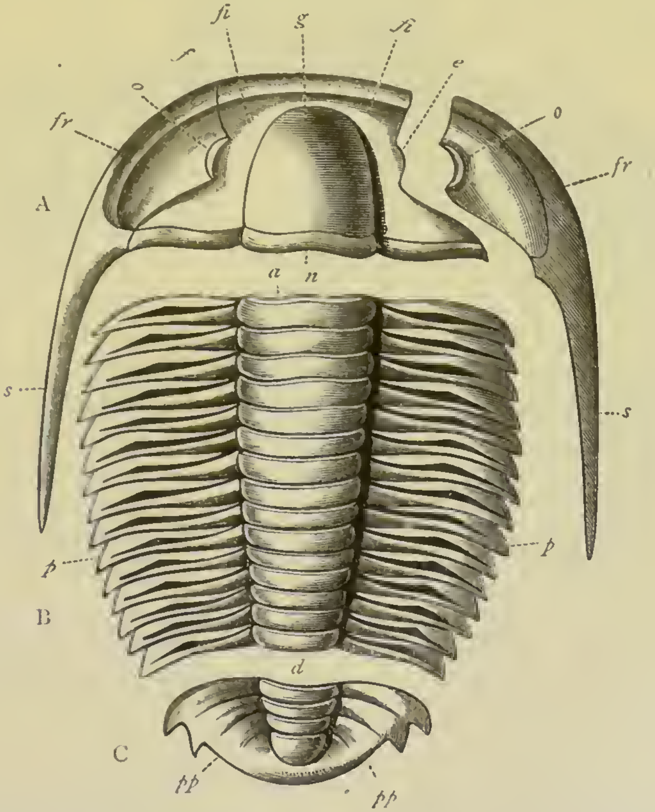

Fig. 192.—The skeleton of a Trilobite (*Angelina Sedgwickii*), partially dissected. A, Head-shield; B, Movable rings of the thorax; C, Tail or abdomen. *g* Glabella (in this species without furrows); *fi* Fixed cheeks; *e* Eye-lobe; *o* Eye; *f* Facial suture; *fr* Free cheeks; *s* Head-spines; *p* Pleuræ; *pp* Anchylosed pleuræ of pygidium.

pieces, of which the two latter may, or may not, be united together in front of the former.

The median portion is usually elevated above the remainder of the cephalic shield, and is called the "glabella"; it protected the region of the stomach, and is usually divided into from three to four lobes by lateral grooves. At each side of the glabella, and continuous with it, is a small semicircular area, called the "fixed cheek." The glabella, with the "fixed cheeks," is separated from the lateral portions of the cephalic shield—termed the "movable" or "free cheeks"—by a peculiar suture or line of division, which is known as the "facial suture," and is quite unknown amongst recent *Crustacea*, except for a faint indication in *Limulus*, and

more or less doubtful traces in certain other forms. The movable cheeks bear the eyes, which are generally crescentic or reniform in shape, are rarely pedunculated (being never supported upon movable foot-stalks), and consist of an aggregation of facets covered by a thin cornea. The

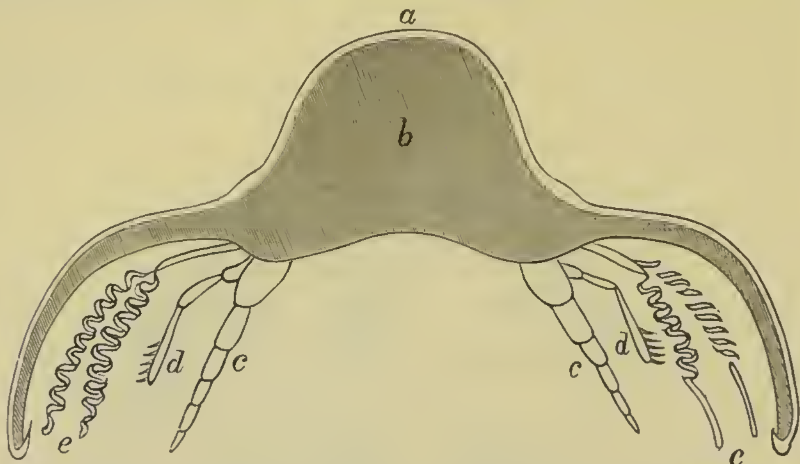

Fig. 193.—Transverse section of the thorax of *Calymene senaria*, partially restored (after C. D. Walcott). *a* Dorsal crust; *b* Visceral cavity, continued laterally to the pleural margins of the dorsal crust; *c* Legs, restored; *d* Epipodite; *e* Spiral gills. Enlarged six times.

facial sutures may join one another in front of the glabella—in which case the free cheeks will form a single piece; or they may cut the anterior margin of the shield separately—in which case the free cheeks will be discontinuous. The posterior angles of the free cheeks are often produced into long spines.

Behind the cephalic shield comes the thorax, composed of a variable number of segments, which are not soldered together, but are capable of free motion upon one another, so as to allow the animal, in many cases, to roll itself up after the manner of a wood-louse or hedgehog. The thorax is usually strongly trilobed, and each thorax-ring shows the same trilobation, being composed of a central, more or less strongly convex, portion, called the "axis," and of two flatter side-lobes, called the "pleuræ."

The "pygidium," or "tail," is usually trilobed also, and, like the thorax, consists of a median axis and of a marginal limb, the composition of the whole out of anchylosed segments being shown by the existence of axial and pleural grooves.

Division C. Merostomata.—The members of this group are Crustaceans, often of gigantic size, in which the mouth is furnished with mandibles and maxillæ, the terminations of which become walking- or swimming-feet, and organs of prehension. Two orders are included under the head of *Merostomata*,—viz., the recent King-crabs (*Xiphosura*) and the extinct Eurypterids. By Professor Claus these orders are regarded as forming a special division of Arthropods, with relationships to the *Arachnida*, to which he applies the name of *Gigantostraca*. Professor Ray Lankester has also shown that there are various

remarkable features of relationship between *Limulus* and the Scorpions; and the same point has been brought out by Van Beneden from his researches into the development of the King-crabs.

ORDER I. XIPHOSURA.—" *Crustacea having the anterior segments welded together to form a broad convex buckler, upon the dorsal surface of which are placed the compound eyes and ocelli, the former sub-centrally, the latter in the centre in front. The mouth is furnished with a small labrum, a rudimentary metastoma and six pairs of appendages. Posterior segments of the body more or less free, and bearing upon their ventral surfaces a series of broad lamellar appendages; the telson, or terminal segment, ensiform*" (Henry Woodward).

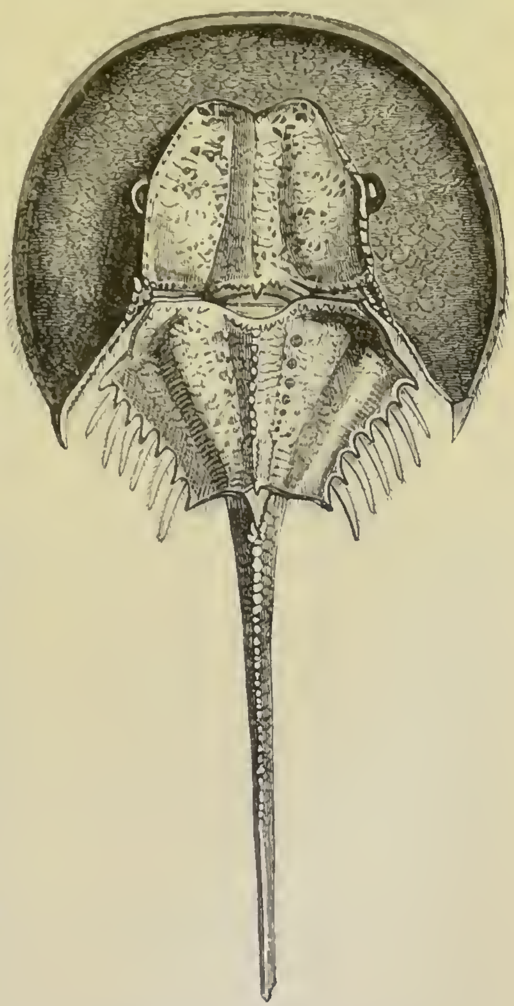

Fig. 194.—*Limulus moluccanus*, viewed from the dorsal aspect, and reduced in size.

The *Xiphosura* include no other recent forms than the *Limuli* (King-crabs, or Horse-shoe Crabs). They are distinguished by the possession of *six pairs of chelate limbs, placed round the mouth, having their bases spinous, and officiating as jaws.* The anterior portion of the body is covered by a broad horse-shoe-shaped buckler (fig. 194), the upper surface of which bears a pair of large compound eyes near its centre, and a second pair of minute eyes situated close together in front. The head-shield consists of six amalgamated segments, and on its lower side (fig. 195) is placed the aperture of the mouth, surrounded by six pairs of limbs, the bases of the last five of which are spinous, and officiate as jaws, while the ter-

minations of all are converted into nipping-claws or "chelæ." The first pair of appendages is placed in front of the mouth, and has been regarded as representing a pair of antennæ.

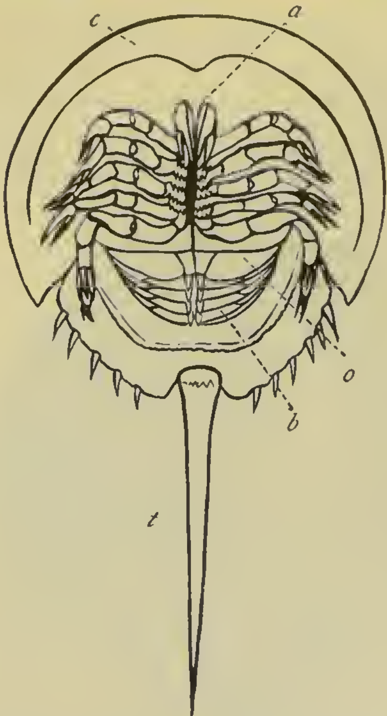

Fig. 195.—Xiphosura. *Limulus polyphemus*, viewed from below. *c* The cephalic shield carrying the sessile eyes upon its upper surface; *o* "Operculum," covering the reproductive organs; *b* Branchial plates; *a* First pair of antennæ (antennules) ending in chelæ. Below these is the aperture of the mouth, surrounded by the spiny bases of the remaining five pairs of appendages, which are regarded by Woodward as being respectively, from before backwards, the great antennæ, the mandibles, the first maxillæ, the second maxillæ, and a pair of maxillipedes. All have their extremities chelate.

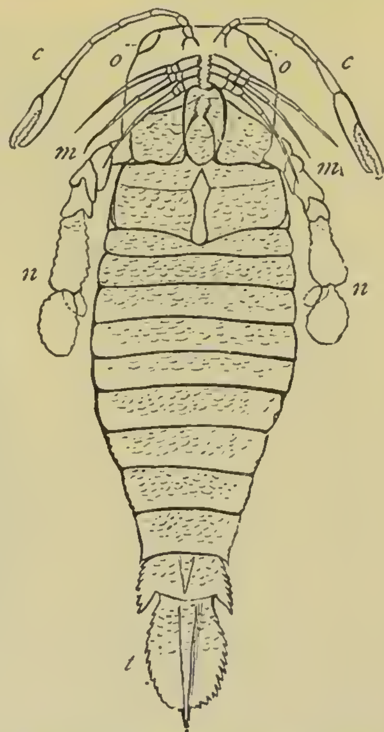

Fig. 196.—Eurypterida. *Pterygotus Anglicus*, restored (after H. Woodward). *c c* Chelate antennæ; *o o* Eyes situated at the anterior margin of the carapace; *m m* The mandibles, and the first and second maxillæ; *n n* The maxillipedes—the basal margins of these are serrated, and are drawn as if seen through the metastoma or post-oral plate, which serves as a lower lip. Immediately behind this is seen the operculum or thoracic plate which covers the two anterior thoracic somites. Behind this are five thoracic and five abdominal somites, and lastly there is the telson (*t*).

Behind the cephalic buckler comes a second shield, composed of eight amalgamated abdominal segments, and movably articulated to the hinder margin of this is a long sword-like anal spine or "telson." On the under side of the abdominal shield are carried five pairs of lamellar appendages, to a large extent concealed beneath a broad lamellar plate or "operculum" (fig. 195, *o*), which protects the openings of the reproductive organs. The abdominal appendages are used in swimming, and also carry delicate closely-set leaf-like organs which act as gills.

The circulatory system of *Limulus* is of a very high type, though the heart is tubular. The venous blood, instead of being contained in the mere interspaces and lacunæ between the tissues, is to a large extent confined within proper vessels. A remarkable peculiarity, also, is that the ventral nerve-cord is enclosed within the abdominal artery, and most of the nerves are similarly ensheathed within the arteries.

The eggs of *Limulus* are laid in the sand, and are fertilised by the male. Just prior to the time of hatching, six segments can be recognised in the cephalothorax; the abdomen consists of nine well-marked somites; the bases of the legs are hardly spinose; and the abdominal spine is quite rudimentary. In this stage (fig. 197), the larva closely resembles some of the Trilobites, such as *Trinucleus*. After hatching, the previously existing segmentation is soon obliterated, and, three or four weeks later, the telson assumes the ensiform shape characteristic of the adult.

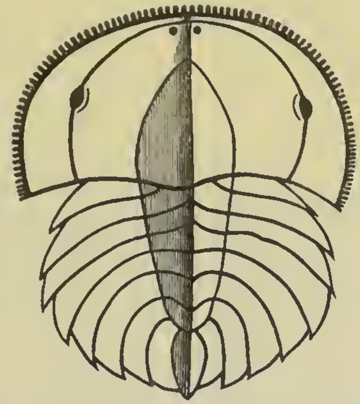

Fig. 197.—Larva of *Limulus* on hatching, greatly enlarged. (After Dohrn.)

As regards their *distribution in space*, there are only two recent species of *Limulus*, of which one (*L. moluccanus*) is confined to the Malayan Archipelago and the eastern shores of Asia, while the other (*L. polyphemus*) is restricted to the eastern coasts of North America. They sometimes attain a length of two feet or more.

As regards their *distribution in time*, species of *Limulus* have been recognised in rocks as old as the Trias or Permian formation; while the remains of various allied types (*Neolimulus*, *Belinurus*, *Euproöps*, *Prestwichia*, &c.) are known in Palæozoic strata, beginning in the Silurian period.

ORDER II. EURYPTERIDA.—"*Crustacea with numerous free, thoracico-abdominal segments, the first and second* (?) *of which bear one or more broad lamellar appendages upon their ventral surface, the remaining segments being devoid of appendages; anterior rings united into a carapace, bearing a pair of larval eyes* (*ocelli*) *near the centre, and a pair of large marginal or subcentral eyes: the mouth furnished with a broad post-oral plate, or metastoma, and five pairs of movable appendages, the posterior of which form great swimming-feet: the telson, or terminal segment, extremely variable in form; the integument characteristically sculptured*" (Henry Woodward).

The *Eurypterida* are all extinct, and are entirely confined to the Palæozoic period, the genera *Pterygotus*, *Eurypterus*, and *Slimonia* being characteristic types. Many of them attained to a comparatively gigantic size; *Pterygotus Anglicus* (fig. 196) being supposed to have reached a length of probably six feet. In their characters they present many larval features, resembling the larvæ of the *Decapoda*, especially, in the fact that all the free somites of the abdomen (except the two anterior ones) were totally devoid of appendages. The oldest examples of the order are found in the Ordovician rocks.

CHAPTER XXX.

MALACOSTRACA.

SUB-CLASS III. MALACOSTRACA (*Thoracipoda*, Woodward).—The *Crustacea* of this sub-class are distinguished by the possession of a generally *definite* number of body-segments; seven somites going to make up the thorax, and an equal number entering into the composition of the abdomen (counting, that is, the telson as a somite). The *Malacostraca* are divided into two primary divisions, termed respectively the *Hedriophthalmata* and the *Podophthalmata*, according as the eyes are sessile or are supported upon eye-stalks.

DIVISION A. HEDRIOPHTHALMATA.—This division comprises those *Malacostraca* in which the eyes are sessile, and the body is mostly not protected by a carapace. It comprises the two orders of the *Isopoda* and *Amphipoda*. The eyes are generally compound, but sometimes simple, and are placed on the sides of the head. The head is almost always distinct from the body, and the mandibles are often furnished with a palp. Typically there are seven pairs of feet in the adult, hence this division has been called *Tetradecapoda* by Agassiz. In certain Isopods (*Tanais*) alone is there a carapace.

ORDER I. AMPHIPODA.—The members of this order are Crustaceans, mostly of small size, in which *the body is laterally compressed, and the thorax consists of seven segments, carrying seven pairs of legs. The abdomen is mostly well developed, and consists of seven segments. The gills are lamellar or vesicular, and are attached to the basal joints of the thoracic legs. The seven pairs of thoracic limbs are directed partly forwards*

and partly backwards. It is from this latter circumstance that the name of the order is derived.

In the typical Amphipods the head is sharply separate from

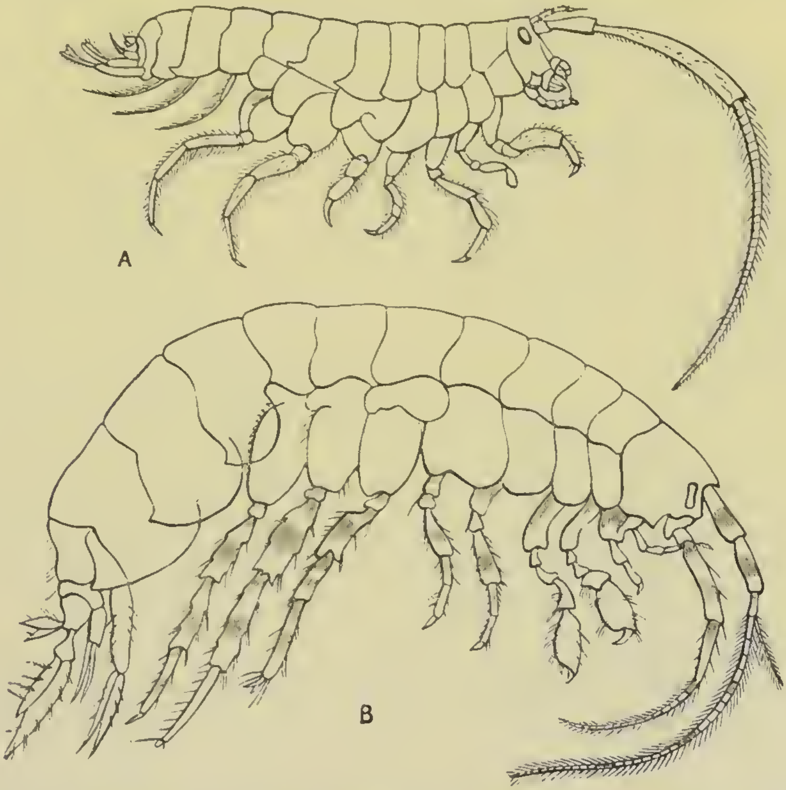

Fig. 198.—Amphipoda. A, *Talitrus locusta*, the "Sand-hopper," enlarged. B, *Gammarus locusta*, enlarged about four times. (After Spence Bate and Westwood.)

the first thoracic segment. The three hindmost pairs of abdominal limbs are bent backwards, and form, with the telson, a natatory or saltatorial tail. Respiration is carried on by delicate lamellæ attached to the bases of the thoracic legs. The heart has the form of a long tube extending through the six segments following the head, and having the blood admitted to its interior by three pairs of valvular fissures. One of the pairs of thoracic legs of the male may be converted into powerful prehensile "claspers," and the females carry about the eggs in an incubatory pouch formed by plates attached to the bases of the thoracic legs.

In the group of small Crustaceans to which the name of *Læmodipoda* has been given, the general structure is much the same as in the typical Amphipods, but the first thoracic ring is fused with the head, and the first pair of legs thus appear

to spring from the under side of the head, or, as it were, beneath the throat (fig. 199). Hence the name of *Læmodipoda.* In these forms also the abdomen is rudimentary, and

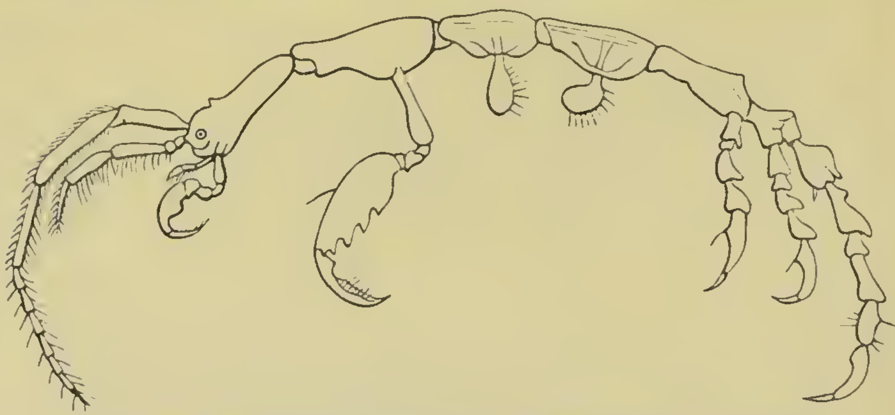

Fig. 199.—Læmodipoda. *Caprella lobata*, enlarged about six times. (After Spence Bate and Westwood.)

the respiratory organs are in the form of membranous vesicles attached to the third and fourth thoracic segments.

The Amphipods have a world-wide distribution, inhabiting both fresh and salt water, or sometimes living inland. The most familiar types of the order are the Sand-hoppers and Shore-hoppers, and the *Gammari.* The common Sand-hopper (*Talitrus locusta*, fig. 198, A) is found everywhere on European coasts, burrowing in moist sea-weed or in sand between tide-marks. They move by means of leaping, as do the very similar Shore-hoppers (*Orchestia*). The *Gammari* are found both in fresh and salt water, the "Fresh-water Shrimp" (*Gammarus pulex*, fig. 198, B) of our pools and streams being a familiar example. They swim on their side.

The commonest British representatives of the *Læmodipoda* are the "Spectre-shrimps" (*Caprella*, fig. 199), which are found upon zoophytes in rock-pools or in shallow water. Another curious type of this group is the Whale-louse (*Cyamus ceti*), which is parasitic on the skin of Cetaceans.

There are various fossil representatives of the *Amphipoda*, of which the oldest is the somewhat doubtful *Necrogammarus* of the Silurian.

ORDER II. ISOPODA.—In this order *the head is always distinct from the segment bearing the first pair of feet. The respiratory organs are not thoracic*, as in the preceding order, *but are attached to the inferior surface of the abdomen, and consist of leaf-like branchiæ, which in the terrestrial species are protected by plates which fold over them. The thorax is com-*

posed of seven segments, bearing typically seven pairs of limbs, which, in the females, have marginal plates, attached to their bases, and serving to protect the ova. The number of segments in the abdomen varies, but is never more than seven. The abdominal segments are coalescent, and form a broad caudal shield, beneath which the branchiæ are carried (fig. 200, A). The heart is sometimes an elongated tube, with

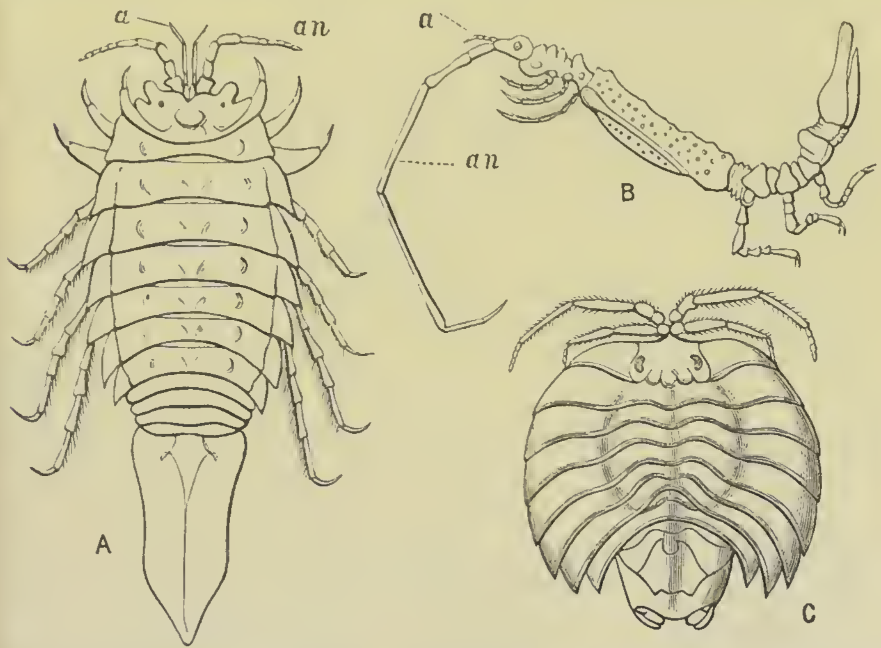

Fig. 200.—Isopoda. A, *Idotea entomon*, enlarged; B, *Arcturus longicornis*, enlarged; C, *Serolis Scythei*: *an* Antennæ; *a* Antennules. (After Gerstaecker, Spence Bate and Westwood, and Lütken.)

three pairs of fissures (as in the *Amphipoda*), sometimes short or spherical, removed towards the abdomen, and with more or fewer fissures than the above. The young Isopod is developed within a larval membrane, and is destitute of appendages. After a time this membrane bursts, and liberates the young, which resembles the adult in most respects, but possesses only six instead of seven pairs of limbs. Of the members of this order, many are aquatic in their habits, and are often parasitic, but others are terrestrial.

Of the numerous groups of the Isopods, onc of the most characteristic is that represented by the common marine genus *Idotea* (fig. 200, A), including the so-called "Box-slaters." The branchiæ are carried in this genus under a long abdominal shield, and are protected by an operculum developed from the last pair of abdominal feet. An allied type is *Arcturus* (fig. 200, B), in which the body is cylindrical, and the young are

carried about by the parent attached to the very long antennæ. Related to the preceding are the Water-slaters (*Asellus*) of ponds and lakes; and in the neighbourhood of this must be placed the singular *Limnoria terebrans*, well known for the destruction which it produces by boring into the wood-work of piers and other structures placed in the sea.

Another group is that of the Fish-slaters (*Cymothoidæ*), in which there is generally a wide abdomen. *Cymothoa* itself is parasitic upon Fishes; but the remarkable genus *Serolis* (fig. 200, C) comprises free-living forms, which have a curious resemblance in shape to the Trilobites. These forms are marine, as likewise are the Bullet-slaters (*Sphæroma*), which have the power of rolling themselves up into a ball.

The family of the *Bopyridæ* includes a number of Isopods which live parasitically in the gill-chambers, or attached to the ventral surface, of certain of the Decapod Crustaceans, such as the Shrimps and the Prawns. A very exceptional type is represented by the Cheliferous Slaters (*Tanais*), in which (as in no other Isopods) a carapace is present, the lateral parts of which are highly vascular, and serve as respiratory organs, while the abdominal feet are used in swimming, and have no branchial function.

The only other family of the Isopods which need be mentioned is that of the Wood-lice and Rock-slaters (*Oniscidæ*). In this group the endopodites of the abdominal feet are branchial, while the exopodites act as opercula to these. The Wood-lice (*Oniscus*, fig. 201) are terrestrial in their habits, but live in places where the air is moist. The nearly allied genus *Armadillo* has the power of rolling itself into a ball, and presents the curious feature that the opercula of the anterior abdominal limbs are provided with internal air-chambers. Lastly, the common Rock-slaters (*Ligia*) live among stones between tide-marks.

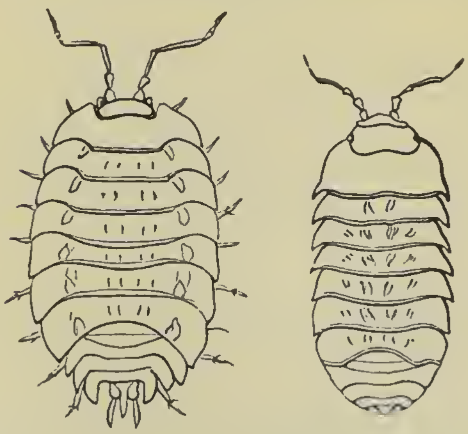

Fig. 201.—Isopoda. Wood-lice (*Oniscus*), twice the natural size.

Many Isopods undergo an extensive metamorphosis. "In some Fish-lice (*Cymothoa*) the young are lively swimmers, and the adults are stiff, heavy, stupid fellows, whose short clinging feet are capable of little movement." In the *Bopyridæ* the adult females are usually blind, the antennæ are rudimentary, and the abdominal appendages from natatory become respiratory organs. The males, on the other hand, are dwarfed, and sometimes lose all the abdominal appendages, and all traces of segmentation; until we get forms which, like *Cryptoniscus planarioides*, "would be regarded as a Flat-worm rather than an Isopod, if its eggs and young did not betray its Crustacean nature" (Fritz Müller).

DIVISION B. PODOPHTHALMATA.—The members of this division have compound eyes supported upon movable stalks or peduncles, and the body is always protected by a cephalothoracic carapace. Most of the *Podophthalmata* pass through Zoea-stages in their development. The division comprises the

three orders of the *Stomatopoda*, *Schizopoda*, and *Decapoda*, of which the last includes the most highly organised and most familiar examples of the class *Crustacea*.

ORDER I. STOMATOPODA (or STOMAPODA).—The Crustaceans of this order have *a short cephalothoracic carapace, which does not protect the hinder segments of the thorax. There are five pairs of maxillipedes, and three pairs of thoracic legs. The branchiæ are not enclosed in a cephalothoracic gill-chamber on each side, but are in the form of tufts attached to the abdominal feet.* The possession of pedunculate eyes distinguishes the *Stomatopoda* from the preceding orders of Crustaceans. The development has not yet been thoroughly investigated.

The only group of Crustaceans now included in this order is that of the "Locust Shrimps" (*Squilla*, fig. 202), all the species of which are inhabitants of the sea. In the *Squillæ* the carapace is small, and does not cover the posterior half of the thorax. The eyes and antennæ are attached to a somite which is not soldered to the cephalothorax. The branchiæ are attached to the first five pairs of abdominal feet. The three posterior thoracic and the abdominal appendages are in the form of "swimmerets," and the tail is expanded into a powerful fin.

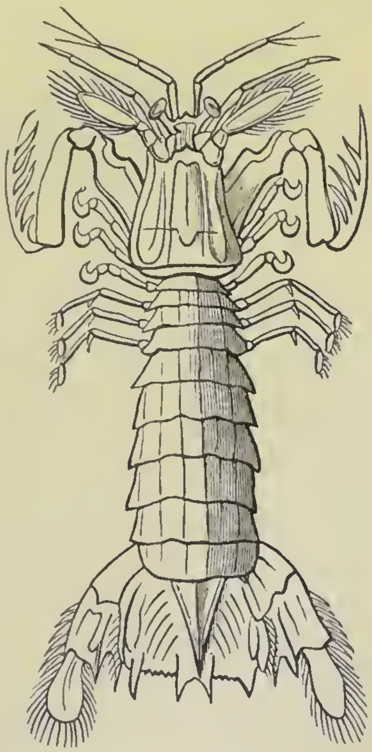

Fig. 202.—*Squilla mantis*, the Locust Shrimp.

The *Stomatopoda* are doubtfully represented by fossil forms in the Carboniferous rocks; but unquestionable examples of the order appear in the Jurassic formation.

ORDER II. SCHIZOPODA.—This order has been established for the Opossum Shrimps (*Mysis*) and their allies, including a number of small Crustaceans, which are in many respects intermediate between the *Stomatopoda* and the *Decapoda*, but are upon the whole most nearly related to the latter. In the Crustaceans of this order, *the thoracic limbs are eight on each side, and are provided each with an exopodite and endopodite* (fig. 203), *the exopodites being natatory in function. A cephalothoracic shield is present, and there is usually*

only a single pair of maxillipedes. The gills are attached to the thoracic legs, or, exceptionally, to the abdominal feet. The ova are carried beneath the thorax of the female, usually in a marsupial pouch formed by leaf-like plates produced from the bases of the legs (fig. 203, *m*).

The Schizopods are distinguished from the Decapods by the

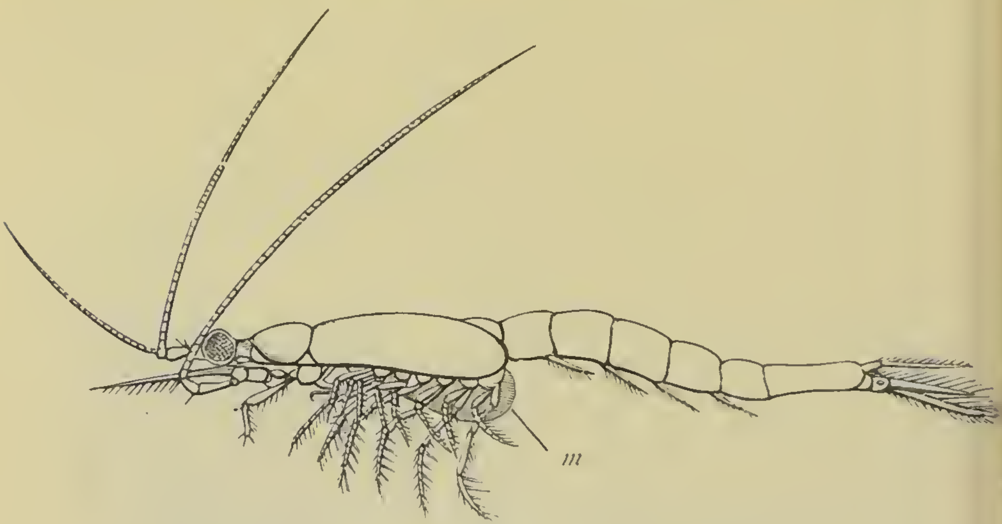

Fig. 203.—"Opossum Shrimp" (*Mysis oculata*). *m* Marsupial pouch. (After G. O. Sars.)

larger number of the thoracic limbs, and by the fact that these appendages have well-developed exopodites, as well as by the fact that the gills are not carried in branchial chambers formed by a downward prolongation of the sides of the carapace. In *Mysis* and its allies true branchiæ are wanting. With the single exception of the *Mysis relicta* of the great lakes of Sweden and North America, all the Schizopods are inhabitants of the sea, extending their range to considerable depths. No undoubted fossil examples of the order have been yet discovered.

ORDER III. DECAPODA.—The members of this order are the most highly organised of all the *Crustacea*, as well as being those which are most familiarly known, the Lobsters, Crabs, Shrimps, &c., being comprised under this head. For the most part they are aquatic in their habits, and they are usually protected by strong resisting shells. There is always a complicated set of "gnathites," or appendages modified for masticatory purposes, surrounding the mouth. *The ambulatory feet are made up of five pairs of legs* (hence the name of the order); *the first pair—and often some other pairs behind this—being*

"*chelate*," *or having their extremities developed into nipping-claws. The branchiæ are pyramidal, and are contained in cavities at the side of the thorax. The carapace is large, covering the head and thorax and the anterior part of the abdomen.* The heart of the *Decapoda* is in the form of a more or less quadrate sac, furnished with three pairs of valvular openings. As regards the development of the Decapods enormous differences obtain, even amongst forms very closely allied to one another.

The *Decapoda* are divided into three tribes, termed respectively the *Macrura*, *Anomura*, and *Brachyura*, and characterised by the nature of the abdomen.

TRIBE A. MACRURA.—The "long-tailed" Decapods included in this tribe are distinguished by the possession of a well-developed abdomen, often longer than the cephalothorax, the posterior extremity of which forms a powerful natatory organ or caudal fin. As regards the development of the *Macrura*, most appear at first in the form of "Zoeæ";* but there is little metamorphosis in the common Lobster, and there is said to be none in the Cray-fish (*Astacus fluviatilis*). Fritz Müller, again, has shown that the primitive form of one of the Shrimps (*Penæus*) is that of a "Nauplius." Lastly, the young of the Spiny Lobster (*Palinurus vulgaris*) are transparent *Phyllosomæ*, resembling Stomatopods in appearance.

One of the most typical forms of the Macrurous Decapods is the common Lobster (*Homarus vulgaris*), the general anatomy of which has been already briefly described. The young of the Lobster when hatched are in many respects like the adult, but the thoracic legs have natatory exopodites (as is permanently the case in the Schizopods), and there are no abdominal appendages. The "Spiny Lobsters" (*Palinurus*) have the carapace prickly, and none of the thoracic legs have true chelæ, the first alone having rudimentary pincers. The "Norway Lobster" (*Nephrops*), on the other hand, has the great chelæ of exceptional length. The Prawns (*Palæmon*)

* The young Decapod, in most cases, leaves the egg in a larval form so different to the adult that it was originally described as a distinct animal under the name of *Zoea*. In this stage (fig. 208) the thoracic segments with the five pairs of legs proper to the adult are either wanting or are quite rudimentary. The abdomen and tail are without appendages, and the latter is composed of a single piece. The foot-jaws are in the form of natatory forked feet, and the mandible has no palp. Lastly, there are no branchiæ, and respiration is carried on by the lateral parts of the carapace. The "Zoea" is separated from the "Nauplius" by having a segmented body, large paired eyes (sometimes with a median eye), and a carapace. The form proper to the adult is not attained until after several moults, constituting a genuine metamorphosis, though one which is effected by very gradual stages.

and Shrimps (*Crangon*) are other common types of the marine *Macrura*. The fresh-water forms of the Macrurous Decapods are commonly known as Cray-fish. The common European Cray-fish (*Astacus fluviatilis*, fig. 204) is in all essential respects

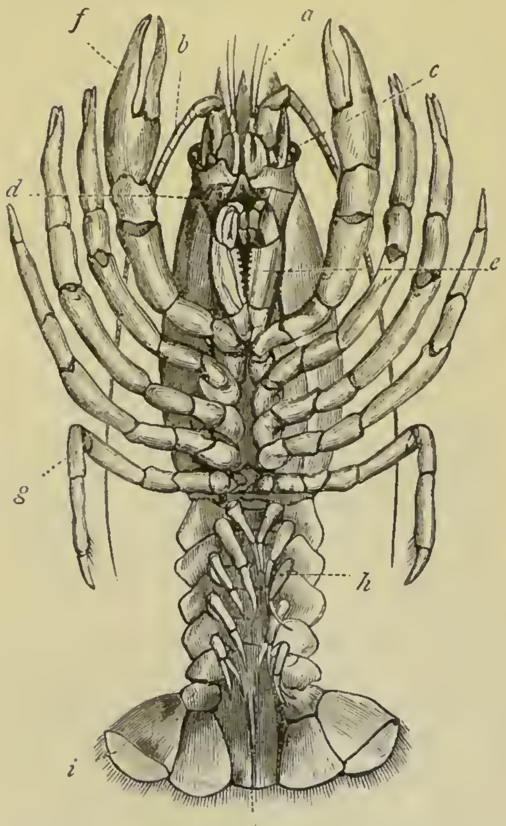

Fig. 204.—The common Cray-fish (*Astacus fluviatilis*), viewed from below. *a* Antennules; *b* Antennæ; *c* Eyes; *d* Opening of antennary gland; *e* Last pair of foot-jaws; *f* One of the great chelæ; *g* Fifth thoracic limb; *h* Swimmerets; *i* The last pair of swimmerets; *j* The opening of the anus below the telson.

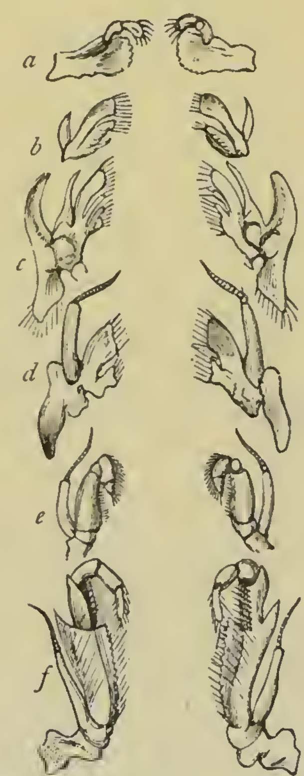

Fig. 205. — Gnathites of the Cray-fish (*Astacus fluviatilis*). *a* Mandibles; *b* Maxillæ; *c* Second pair of maxillæ; *d* First pair of foot-jaws; *e* Second pair of foot-jaws; *f* Third pair of foot-jaws.

similar in its characters to the common Lobster, but the last thoracic segment is partially free, and the scale which represents the exopodite of the great antennæ is of comparatively large size; while there are other less noticeable structural differences as well. The Cray-fishes of North America, east of the Rocky Mountains, have been referred by Professor Huxley to a separate genus (*Cambarus*). In the Cray-fishes of the south hemisphere (*Parastacidæ*) the first abdominal segment is destitute of any appendage. As regards their development, there does not seem to be any metamorphosis properly so-

called in the Cray-fishes, the young when hatched differing from the adult in minor characters only.

TRIBE B. ANOMURA.—The Decapods which belong to this tribe are distinguished by the condition of the abdomen, which is neither so well developed as in the *Macrura*, nor so rudimentary as in Crabs. The last pair of thoracic limbs are reduced in size. Further, the abdomen does not terminate posteriorly in a caudal fin, as in the Lobster. The development in the *Anomura* appears invariably to take place through Zoea-forms.

The entire group of the *Anomura* must be regarded as an artificial assemblage, composed of modified forms of both the *Macrura* and the *Brachyura*.

The most familiar of the *Anomura* are the Hermit-crabs (*Paguridæ*). In the common Hermit-crabs (*Pagurus*) the abdomen is quite soft, and is merely enclosed in a membrane, so that the animal is compelled to protect itself by adopting the empty shell of some Mollusc, such as the common Whelk, which it changes at will when too small. The anterior abdominal appendages are wanting, but rudimentary feet are developed, often on one side only, at the hinder end of the abdomen, and by means of these the animal is enabled to retain his position within his borrowed dwelling. One of the chelæ is bigger than the other, and acts as a kind of stopper to the mouth of the shell, when the Hermit is withdrawn within it.

Allied to the *Paguri* are various Hermits which are ter-

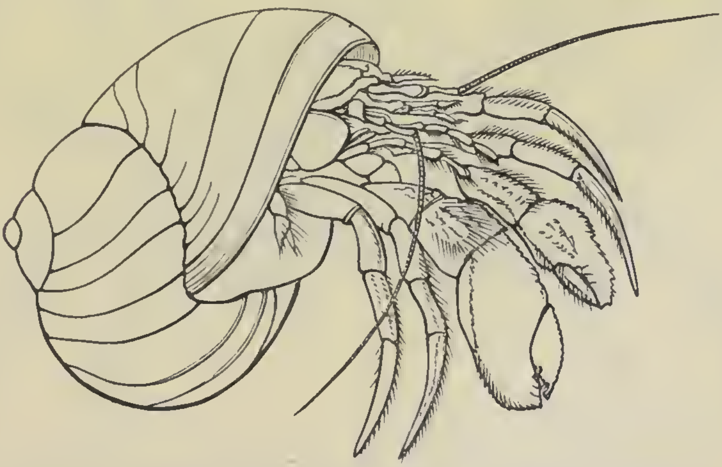

Fig. 206.—Hermit-crab (*Cœnobita*) in its borrowed shell. After Morse.

restrial in their habits, and often live far away from the sea. Good examples of these Land-hermits are the common *Cœnobitæ* of the tropics (fig. 206), which protect themselves within

the shell of some terrestrial Mollusc. The Tree-crabs (*Birgus*) also live inland, and are stated to climb trees. The "Plated Lobsters" (*Galathea*) are not unlike Cray-fish in general appearance, but the last pair of thoracic legs are rudimentary. On the other hand, the "Crab-lobsters" (*Porcellana*), and the "Stone-crabs" (*Lithodes*) have the abdomen bent under the thorax, and thus approach the true Crabs in general aspect.

TRIBE C. BRACHYURA.—The "short-tailed" Decapods, or Crabs, are distinguished from the two preceding tribes by the rudimentary condition of the abdomen, which is very short, and is tucked up beneath the cephalothorax, the latter being disproportionately large. There is no caudal fin, and there are from one (males) to four (females) pairs of abdominal appendages, which are employed by the females in carrying

Fig. 207.—Brachyura. The Spiny Spider-crab (*Maia squinado*).

the ova. The Crabs (fig. 207) are mostly furnished with ambulatory limbs, and are rarely formed for swimming, most of them being littoral in their habits, and some even living inland.

In all the essential points of their anatomy the Crabs do not differ from the Lobster and the other *Macrura;* but they are decidedly higher in their organisation. This is especially seen in the disposition of the nervous system, the ventral ganglia in the Crab being concentrated into a single large ganglion, from which nervous filaments are sent to all parts of the body. In the Land-crabs (*Gecarcinus*) respiration is by branchiæ, but there is almost always an aperture behind the carapace for the admission of air. They are distributed over the warm countries of the Old and New Worlds, as well as Australia. They are essentially terrestrial in their habits, and migrate in large bodies to the sea, in order to lay their eggs. Besides the true *Gecarcini*, members of other very different families live more or less constantly on dry land, and have air admitted into the branchial chamber. Amongst these are the Calling-crabs (*Gelasimus*) and the Sand-crabs (*Ocypoda*).

Reproduction in the Crabs is the same as in the *Macrura*, but the larva is exceedingly unlike the adult, and approximates closely to the type of the *Macrura*, another proof that the *Brachyura* stand higher in the Crustacean scale. The larval Crab was originally described as a distinct animal, under the name of *Zoea* (fig. 208), presenting in this condition a long and well-developed abdomen. It is only after several successive moults that the young Crab assumes its characteristic Brachyurous form, and acquires by gradual changes the features which distinguish the adult. The *Zoeæ* of the Crabs are usually distinguished by the possession of long spines developed from the carapace. When first liberated from the egg, the Zoea is enveloped in a larval skin or membrane, which is shed in a

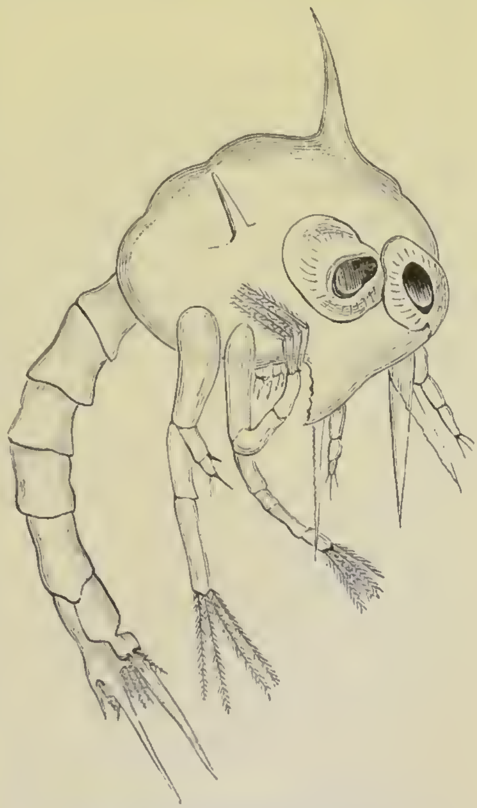

Fig. 208.—Zoea of the Spiny Spider-crab (*Maia squinado*), enlarged.

few hours. From its Zoea-stage, the young Crab passes into what is known as the "Megalopa-stage." In this phase of its development, there are two pedunculated eyes, the cephalothorax is rounded, and the proper five pairs of ambulatory limbs are present. The abdomen is well developed, and projects backwards, its hinder segments being furnished with natatory appendages. At its final moult the abdomen becomes tucked up underneath the cephalothorax. Among the Land-crabs, the young of *Gecarcinus* appear to pass through no metamorphosis; but in some of the *Gecarcinidæ* the larvæ pass through Zoea-stages.

Among the common British forms of the *Brachyura* are the Shore-crab (*Carcinus mænas*), the Edible Crab (*Cancer pagurus*), the Spider-crabs (*Maia* and *Hyas*), the Swimming-crabs (*Portunus*), and the Pea-crabs (*Pinnotheres*). These last live as commensals in the interior of the Horse-mussel and other Bivalve Molluscs.

As regards the distribution of the Decapod Crustaceans *in time*, the *Macrura* are known to have commenced their existence as early as the Devonian or Carboniferous; and they attain their maximum as fossils in the Mesozoic period. Little is known as to the geological distribution of the *Anomura*. A few Brachyurous forms, more or less problematical in their nature, have been indicated as occurring in Palæozoic strata; but various undoubted Crabs have been recognised in Mesozoic deposits, and the tribe is well represented in Tertiary rocks.

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CHAPTER XXXI.

ARACHNIDA.

Class II. Arachnida. — The *Arachnida* — including the Spiders, Scorpions, Mites, &c.—possess almost all the essential characters of the *Crustacea*, to which they are very closely allied. Thus, the body is divided into a variable number of somites, some of which are always provided with articulated appendages. A pair of ganglia is primitively developed in each somite, and the neural system is placed ventrally. The heart, when present, is always situated on the opposite side of the alimentary canal to the chain of ganglia. The respiratory organs, however, whenever these are differentiated, are never in the form of branchiæ as in the *Crustacea*, but are in the form either of pulmonary vesicles or sacs, or of ramified tubes, formed by an involution of the integument, and fitted for breathing air directly. Further, there are never more than four pairs of ambulatory limbs, and no locomotive appendages are developed upon any of the abdominal segments. Antennæ are not present (as such), and the eyes are simple and sessile. The head and thorax are united to form a cephalothorax (the thoracic segments in rare cases remaining free), and in some cases the cephalothorax is fused with the abdomen.

Speaking generally, therefore, the *Arachnida* are distinguished from the *Crustacea* by the possession of four pairs of walking legs, the want of locomotive appendages on the abdomen, and the absence of antennæ; while the breathing-

organs (when differentiated) are adapted for breathing air directly, and are never in the form of branchiæ.

In many of the *Arachnida* the integument remains soft over the entire body; in others, as in the majority of Spiders, the abdomen remains soft and flexible, whilst the cephalothorax is more or less hard and chitinous; in the Scorpions, again, the integument over the whole body forms a strong chitinous shell. The cephalothorax may be segmented (*Solpugidæ*), and the abdomen may or may not be segmented. Though four pairs of legs are typically present, the first is often regarded as homologous with the labial palpi of the *Insecta*.

The typical somite of the *Arachnida* is constituted upon exactly the same plan as that of the *Crustacea*, consisting essentially of a dorsal and ventral arc; the former composed of a central piece, or "tergum," and of two lateral pieces, or "epimera"; whilst the latter is made up of a median "sternum" and of two lateral "episterna."

As regards the composition of the cephalothorax of Spiders, "the tergal elements of the coalesced segments are wanting, and the back of the thorax is protected by the elongation, convergence, and central confluence of the epimeral pieces; the sternal elements have coalesced into the broad plate in the centre of the origins of the ambulatory legs, from which it is separated by the episternal elements. . . . The non-development of the tergal elements explains the absence of wings" (Owen).

The mouth is situated, in all the *Arachnida*, in the anterior segment of the body, and is surrounded by suctorial or masticatory appendages. In the higher *Arachnida*, the mouth is provided from before backwards with the following appendages (fig. 209): 1. A pair of "cheliceræ," "falces," or "mandibles," used for prehension; 2. A pair of "maxillæ," each of which is provided with a long jointed appendage, the "maxillary palp"; 3. A lower lip, or "labium." In the Scorpion, an upper lip, or "labrum," is also present.*

In the lower *Arachnida*, the organs of the mouth, though essentially the same as in the higher forms, are often enveloped in a sheath formed by the labium and maxillæ, whilst the

* The nomenclature ordinarily applied to the parts of the mouth in the *Arachnida* is a misleading one, so far as the homologies of this class with the *Insecta* are concerned. Thus the so-called "mandibles" are really the *antennæ;* the "mandibles" themselves are absent, but the "chelæ" of the Scorpions may perhaps represent the "*mandibular palpi*"; whilst the first pair of *legs* probably correspond with the "*labial palpi*," and the second pair of legs may possibly be a modification of a second pair of palps.

mandibles are often joined together so as to constitute a species of lancet.

With regard to antennæ, these organs, *as such*, do not exist

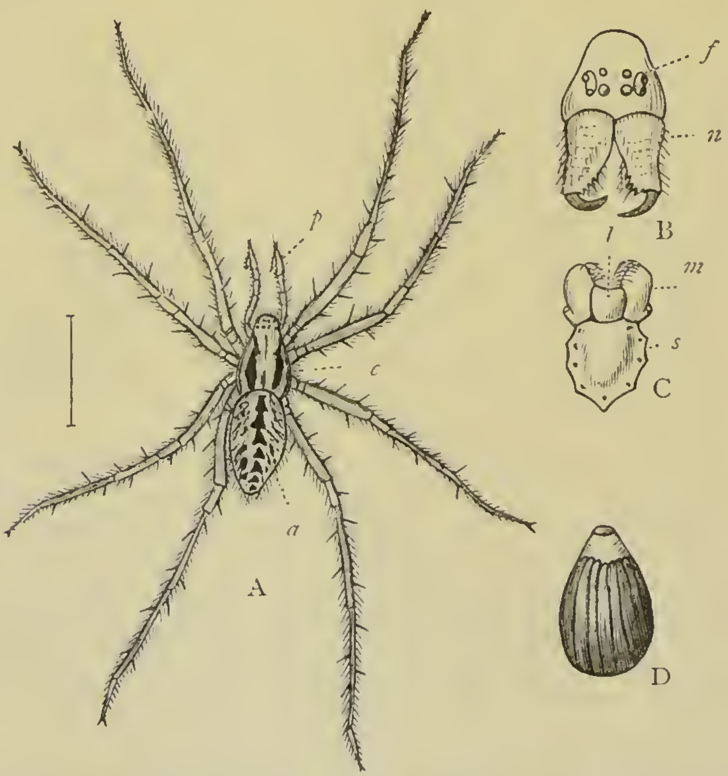

Fig. 209.—A, The male of the common House-Spider (*Tegenaria civilis*), considerably magnified: *c* Front portion of the body, consisting of the amalgamated head and thorax; *p* Maxillary palpi; *a* Abdomen. B, Front portion of the head of the same, showing the eight eyes (*f*), and the mandibles (*n*). C, Under side of the head and trunk, showing the maxillæ (*m*), the lower lip (*l*), and the horny plate (*s*), to which the legs are attached. D, Diagram of one of the air-chambers or pulmonary sacs. (Figs. A, B, and C are after Blackwall.)

in the *Arachnida*. It is generally believed, however, that the *mandibles* of the *Arachnida* are truly homologues, not of the parts which bear the same name in the other *Arthropoda*, but of the *antennæ;* and the name of "falces" is thus best applied to them. The antennæ, therefore, of the Spiders are converted into prehensile and offensive weapons; whilst in the Scorpions, as in the King-crabs, they are developed into nipping-claws, or chelæ.

The mouth opens into an œsophagus (fig. 210, *œ*), into which salivary glands pour their secretion, and this conducts to a wider portion of the alimentary canal, which is usually spoken of as the "stomach," and which has appended to its sides long cæcal diverticula (fig. 210, *s*). From the stomach

the intestine is directed backwards to its termination in a dilated "cloaca" (fig. 210, *c*), without the intervention of any convolutions. After it has entered the abdomen, the intestine, in the higher *Arachnida*, receives the openings of a number of ducts proceeding from a well-developed liver. Lastly, opening into the cloaca are tortuous tubes (fig. 210, *m*), which represent the "Malpighian tubes" of Insects, and have a renal function.

The circulation in the *Arachnida* is maintained by a dorsal heart, which is situated above the alimentary canal, and is wanting in the lower forms. Usually the heart is greatly elongated, and resembles the "dorsal vessel" of the *Insecta*. In the lower *Arachnida*, however, there is no central organ of the circulation, and there are no differentiated blood-vessels. All the *Arachnida*, except some of the lowest, breathe the air directly, and the respiratory function is performed by the general surface of the body (as in the lowest members of the class), or by ramified air-tubes, termed "tracheæ," or by distinct pulmonary chambers or sacs; or, lastly, by a combination of tracheæ and pulmonary vesicles. The "tracheæ" consist of ramified or fasciculated tubes, opening upon the surface of the body by distinct apertures, called "stigmata." The walls of the tube are generally prevented from collapsing by means of a chitinous fibre or filament, which is coiled up into a spiral, and is situated beneath the epithelial lining. The pulmonary sacs, or "tracheal lungs," are simply involutions of the integument, abundantly supplied with blood; the vascular surface thus formed being increased in area by the development of a number of close-set membranous lamellæ, or vascular plates, which project into the

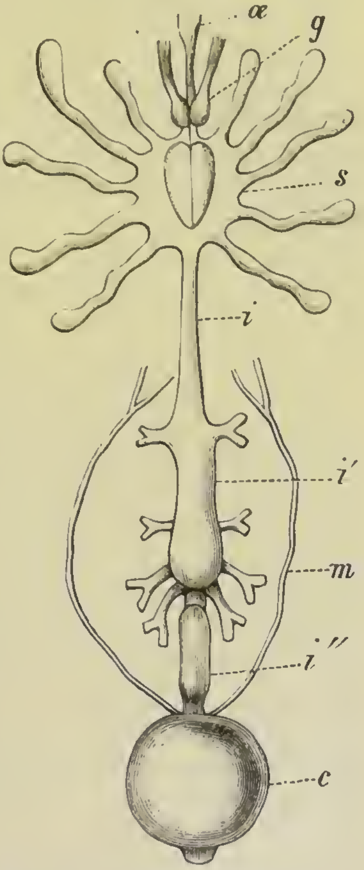

Fig. 210.—Alimentary canal of a Spider (after Dugès). *æ* Œsophagus, with the cerebral ganglion (*g*) lying upon it; *s* Stomach, with five lateral cæca on each side; *i* First part of the intestine where it passes through the peduncle of the abdomen; *i′* Middle portion of the intestine, where the hepatic ducts open into it; *i″* Terminal portion of the intestine, opening into the cloaca (*c*); *m* Malpighian tubes, opening into the cloaca.

interior of the cavity. Like the tracheæ, the pulmonary sacs communicate with the exterior by minute apertures, or "stigmata," and they are to be regarded as being simply greatly expanded tracheæ.

The nervous system is of the normal articulate type, but is often much concentrated. Typically there is a cephalic or "cerebral" ganglion, a large thoracic ganglion, and often small abdominal ganglia. In some of the lower forms the articulate type of nervous system is lost, and there is merely a ganglionic mass situated in the abdomen. In none of the *Arachnida* are compound eyes present, and in none are the eyes supported upon foot-stalks. The organs of vision, when present, are in the form of from two to eight or more simple eyes, or "ocelli."

In all the *Arachnida*, with the exception of the *Tardigrada*, the sexes are distinct. The great majority of the *Arachnida* are oviparous, and in most cases the larvæ are like the adult in all except in size. In some cases, however (*Acarina*), the larvæ have only six legs, and do not attain the proper four pairs of legs until after some moults.

Distribution of Arachnida in Time.—The remains of *Arachnida* in the fossil condition are necessarily very rare. The earliest known types belong to the Scorpions, and have been found in the Silurian rocks (*Palæophonus*). In the Carboniferous rocks both Scorpions and true Spiders are found, the former being represented by the celebrated *Cyclophthalmus senior* from the Coal-measures of Bohemia, and by the *Eoscorpius carbonarius* of the Carboniferous strata of Illinois. Other Carboniferous *Arachnida* have been referred to the genera *Eophrynus*, *Architarbus*, and *Mazonia*. Spiders are also known to occur in the Jurassic rocks (Solenhofen Slates) and in the Tertiary period. The Mites, Harvest-spiders, and Book-scorpions have been detected in amber.

CHAPTER XXXII.

DIVISIONS OF THE ARACHNIDA.

The class of the *Arachnida* may be divided into the following orders:—

Order I. Podosomata (*Pantopoda* or *Pycnogonida*).—

Respiration effected by the general surface of the body; locomotive limbs four pairs in number, elongated; an additional pair of "ovigerous legs" attached to the head; abdomen rudimentary, unsegmented; sexes distinct.

The members of this order, sometimes called "Sea-spiders," have been placed alternately amongst the *Arachnida* and the *Crustacea*, their true position being rendered doubtful by the fact that, though marine in their habits, they possess no differentiated respiratory organs. They possess, however, no more than four proper pairs of legs, and would therefore appear to be properly referable to the *Arachnida*. According to Dr Dohrn, however, the embryo is naupliiform, and this would support a reference of the order to the *Crustacea*.

The Pycnogonids possess a body of four segments, of which the first is really a cephalothorax, formed by the fusion of the head with the first thoracic segment. This carries a long proboscis, at the end of which is the suctorial mouth. The cephalic region carries as a rule three pairs of appendages—viz., (1) a pair of "mandibles," representing the antennæ; (2) a pair of palpi; and (3) a pair of leg-like organs which are known as the "ovigerous legs." These last are used by the males (and exceptionally by the females) to carry the ova, but in both sexes they are tactile and prehensile organs. The thoracic portion of the cephalothorax and the three free segments of the thorax carry four pairs of long eight-jointed legs (fig. 211). The abdomen is quite rudimentary, and is reduced to a mere tubercle, at the end of which the anal opening is placed. The stomach has long cæcal diverticula, which are prolonged into the legs, as are also the reproductive organs. Respiration is effected by the surface of the body, the chitinous cuticle having numerous cavities which communicate with the exterior by minute canals. The nervous system consists of a cerebral ganglion and five thoracic ganglia. The sexes are distinct, and the larvæ as a rule are at first devoid of the four pairs of locomotive legs.

The commoner forms of the *Podosomata* (such as *Nymphon* and *Pycnogonum*) may be found on the sea-coast at low water, crawling about amongst marine plants or hiding beneath stones. Some species of the latter genus are parasitic upon fishes and other marine animals, but the common British species (*P. littorale*) is free when adult, and does not appear to be parasitic at any stage of its existence. The Pycnogonids rarely range below depths of 500 fathoms, but some of the species from deeper water are of very large size, one form measuring a foot or more across the extremities of its limbs.

ORDER II. ACARINA or MONOMEROSOMATA.—The members of this order possess *an unsegmented abdomen which is fused with the cephalothorax into a single mass. Respiration*

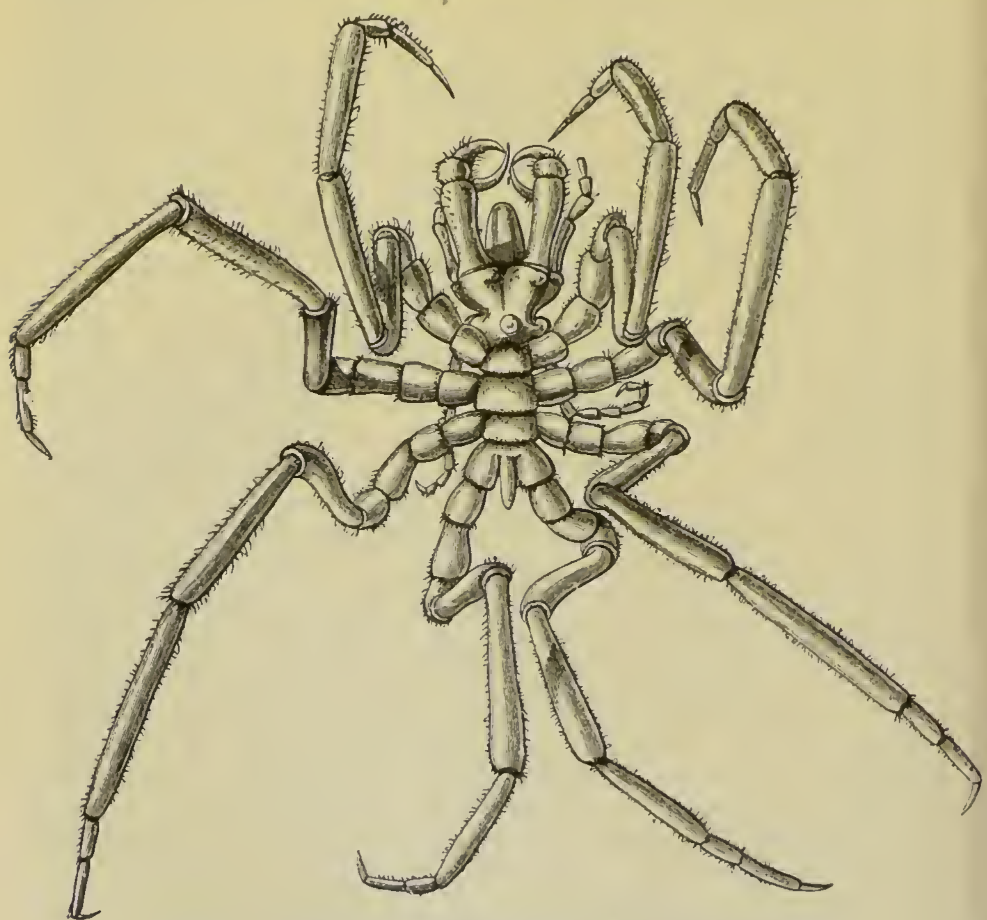

Fig. 211.—Podosomata. *Nymphon abyssorum*, slightly enlarged. (After Sir Wyville Thomson.)

is effected by tracheæ, or by the integument. Most of the *Acarina* are parasitic, and the most familiar are the Mites and Ticks.

Sub-order 1. *Pentastomida* (*Linguatulinæ*).—The members of this family are worm-like parasites, which in their adult state are found in the interior of the frontal sinuses, the nose, or the lungs of the dog, and of other Vertebrate animals. When fully grown (fig. 212) they are completely vermiform, with a soft annulated integument, and possessing no external organs except two pairs of retractile hooks, representing limbs, placed near the mouth. The adult thus presents an external resemblance to the *Tæniæ*, from which, however, they are separ-

ated by the details of their internal organisation. There are no differentiated organs of respiration or circulation, but the sexes are distinct. The larvæ (fig. 212, B) are found encysted in the liver or other internal organs of various Vertebrates (including man), and possess two pairs of articulated limbs.

The best-known type of this group is the *Pentastoma tænioides* (fig. 212), of which the male is only three-quarters of an inch or so in length, while the female reaches a length of three inches. The larvæ live in the liver of the rabbit and hare, and occasionally of man, in an encysted state; and the adult is found in the nose and frontal sinuses of the dog and wolf.

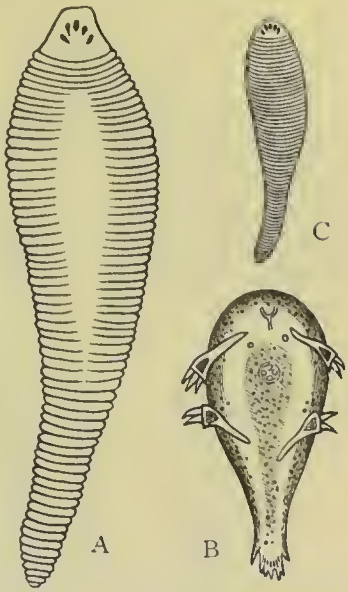

Fig. 212.—A, *Pentastoma tænioides*, female, of the natural size; C, Male of the same, of the natural size; B, Larva of the same, greatly enlarged, showing the two pairs of articulated limbs. (After Spencer Cobbold and Leuckart.)

Sub-order 2. *Tardigrada* (*Macrobiotidæ* or *Arctisca*).—This family comprises the so-called "Sloth" or "Bear Animalcules," which are microscopic animals found in damp moss and in the gutters of houses, or in a few cases on the sea-beach (fig. 213, B). In form, the body is somewhat vermiform, with four pairs of short rudimentary legs. The mouth is suctorial, with rudimentary jaws or stylets. They exhibit no traces of respiratory or circulatory organs, and, unlike the other Arachnids, they have the sexes united in the same individual. The stomach has numerous racemose cæca appended to it; and the head bears two minute eyes. The Tardigrades can survive desiccation, and will return to life on being moistened.

Sub-order 3. *Acarida.*—In this family are the Mites and Ticks, all of which are characterised by the fusion of the cephalothorax and abdomen into a single mass (fig. 214), while the mouth is formed for piercing and suction, or for biting. Definite respiratory organs are sometimes not differentiated; but, when present, they are in the form of tracheæ. The nervous system is in the form of a common ganglionic mass traversed by the œsophagus. No dorsal vessel (heart) is present. The young, and some adult forms, are hexapod. The Mites have a world-wide distribution, and are found in

all sorts of situations. Most are terrestrial in their habits, and a great many are either parasites on animals, or live on the juices of plants. Some forms live in fresh water (*Hydrachna*), and a few types (*Thalassarachna*, *Pontarachna*, &c.), inhabit the sea, while some of the *Trombididæ* live between tide-marks.

The typical Mites (*Tyroglyphidæ*) feed upon animal or vegetable substances, and have scissor-shaped or needle-shaped mandibles adapted for biting. A good example is the common Cheese-mite (*Tyroglyphus domesticus*). Certain of the Mites of this group are parasitic in their habits, living either upon the skin or sometimes within the body of various animals. One of the best known of these is the Itch-mite (*Sarcoptes scabiei*, fig. 213, C), which gives rise to the disease known as the "itch." The

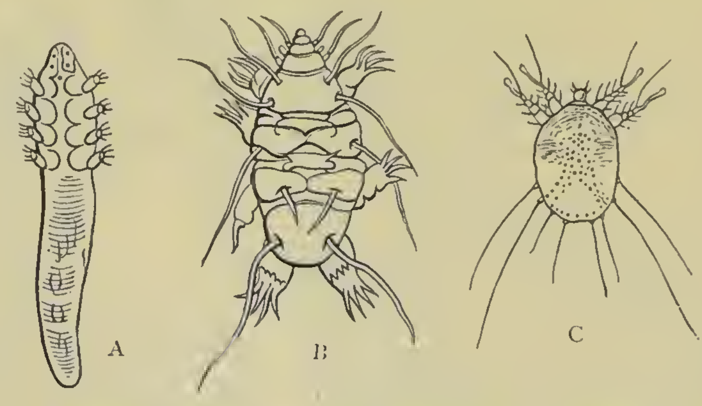

Fig. 213.—A, *Demodex folliculorum*, greatly magnified. B, *Emydium testudo*, one of the *Tardigrada*, greatly magnified. C, *Sarcoptes scabiei*, the Itch-mite, greatly magnified.

females of the *Sarcoptes* live in little tunnels under the epidermis, and have the two anterior pairs of limbs terminated with suckers, while the two hinder pairs end in bristles. The males are much smaller than the females, and live on the surface of the skin. Another form which is parasitic on man is the curious *Demodex folliculorum* (fig. 213, A), which is found inhabiting the hair-follicles and sebaceous glands, especially in the vicinity of the nose. It is questionable if any individuals are absolutely exempt from this harmless parasite, and allied forms attack other species of Mammals.

The true Ticks (*Ixodidæ*) have a leathery and very distensible skin (fig. 214, B). The mandibles are protrusible, serrated, or armed with curved hooks (fig. 214, C), and are used for piercing. The Ticks frequent trees, bushes, or herbage, and attach themselves to passing animals, into the skin of which they bore with their pointed rostrum. When distended with blood, they drop off from their temporary host.

The *Gamasidæ* (Spider-mites or Beetle-mites) are often ecto-parasitic on beetles or other animals, though sometimes leading a free life. The Mite (*Dermanyssus avium*) which causes the "itch" of poultry, belongs to this group, as do some allied forms which live on Bats.

The Water-mites (*Hydrachnidæ*) have fringed legs adapted for swimming, and in their adult state usually lead a free life in water, though

sometimes parasitic in Bivalve Molluscs. The larvæ are hexapod, with a suctorial mouth, and attach themselves as parasites to Water-beetles and other aquatic insects.

The Harvest-mites and Garden-mites (*Trombidiidæ*) are vegetable-feeders,

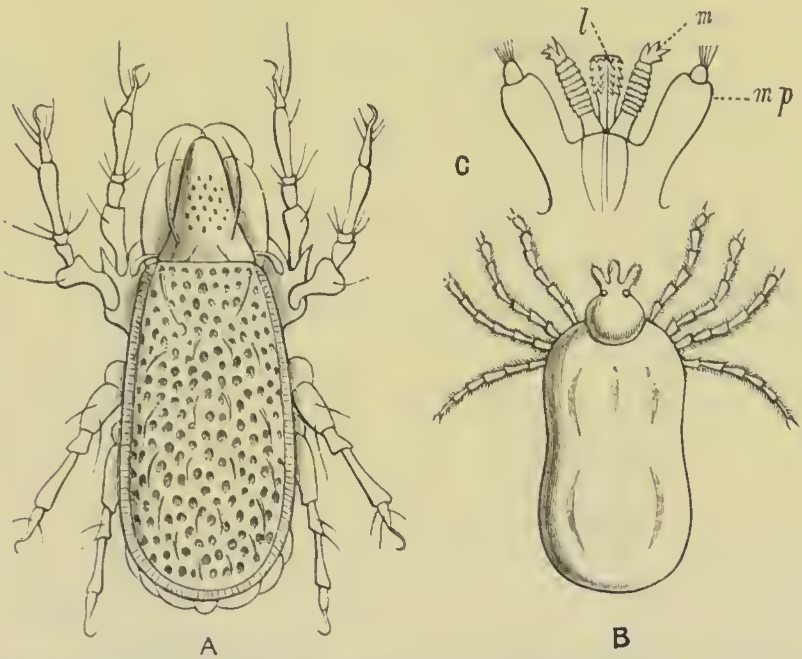

Fig. 214.—Acarina. A, *Tegeocranus elongatus*, enlarged 65 times. B, *Ixodes ricinus*, one of the Ticks, greatly enlarged. C, Mouth-organs of a Tick (*Ixodes albipictus*), enlarged: *l* Labium; *m* Mandibles; *mp* Maxillary palpi. (After Michael, Packard, and Cuvier.)

and live upon plants, the juices of which they extract by their suctorial mouths. Other forms, however, are animal-feeders, and are often parasitic in their larval stages. The common Scarlet-mite (*Trombidium holosericeum*) is a good example of this group. Lastly, the little Mites known as the Beaked-mites (*Bdellidæ*) have the front part of the head constricted off from the rest of the body.

ORDER III. ADELARTHROSOMATA.—The members of this order, comprising the Harvest-spiders, the Book-scorpions, &c., are distinguished from the preceding by the possession of an *abdomen, which is more or less distinctly segmented, but generally exhibits no line of separation from the cephalothorax, the two regions being of equal breadth and conjoined together. The mouth is furnished with masticatory appendages, and respiration is effected by tracheæ, which open on the lower surface of the body by two or four stigmata.*

Sub-order 1. *Phalangidea.*—The well-known "Harvest-men" belong to this group. They are characterised by the great length of the legs (fig. 215, B), and by the filiform maxillary

palpi, terminated by simple hooks. The abdomen and cephalothorax are of about equal width, but clearly marked off from one another, and the former is segmented. There are two eyes, and the young pass through no metamorphosis. The Harvestmen are active in their habits and live upon animal food.

Sub-order 2. *Pseudoscorpionidæ* (*Cheliferidæ*). — The members of this little group are readily recognised by the fact that the maxillary palpi (fig. 215, A) are of large size, and are con-

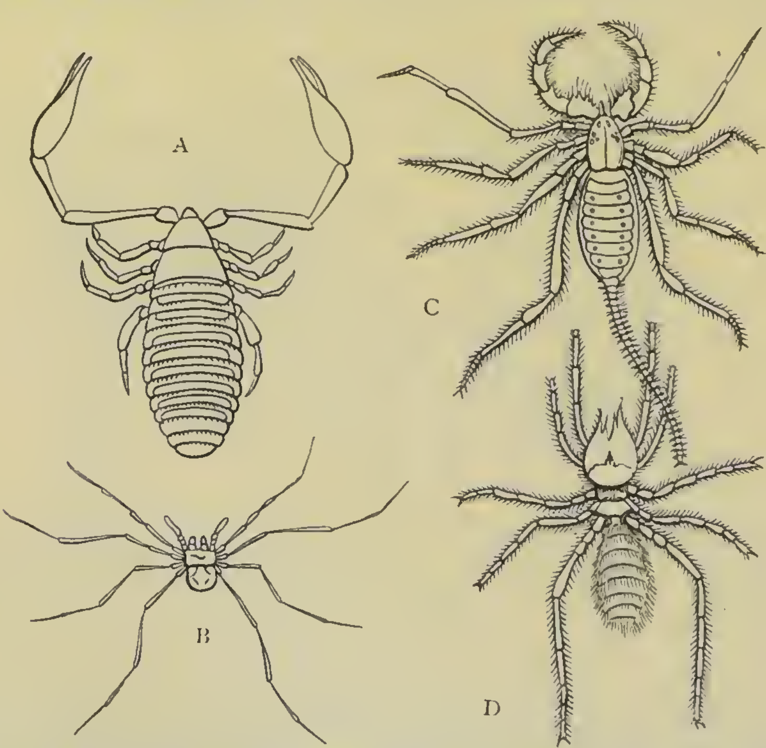

Fig. 215.—A, *Chelifer cancroides*, showing the chelate maxillary palpi, considerably enlarged. B, *Phalangium copticum*, of the natural size. C, *Thelyphonus giganteus*. D, *Galeodes araneoides*, of the natural size.

verted into nipping-claws or chelæ, thus giving the animal the appearance of a Scorpion in miniature. The abdomen is segmented, but there is no "post-abdomen," as in the true Scorpions. Eyes may be wanting, and the under surface of the abdomen carries a small spinning-organ. The "Book-scorpion" (*Chelifer*) is commonly found in old books and in dark places, and feeds upon insects. Other forms are parasitic on Flies and Beetles.

Sub-order 3. *Solpugidea.*—In this family (fig. 215, D) the abdomen is not only very distinctly segmented, but is also clearly separated from the cephalothorax, which latter region exhibits the remarkable peculiarity of being itself distinctly

divided into a head and three separate thoracic segments. The falces or mandibles are chelate, and of immense size; and the maxillary palpi constitute long feet. The front of the head carries two eyes, and respiration is by tracheæ. *Galeodes* may be considered as the type of the group, all the members of which are tropical or subtropical in their range, and are nocturnal and carnivorous in habit.

ORDER IV. PEDIPALPI.—*Abdomen segmented, with or without a "post-abdomen." Respiration by means of pulmonary sacs.* In this order are the true Scorpions, together with certain other animals which are in some respects intermediate between the Scorpions and the true Spiders. The members of this order are distinguished by the fact that the abdomen in all is distinctly segmented, but is not separated from the cephalothorax by a well-marked constriction. They agree in this character with the *Adelarthrosomata;* hence the two are sometimes united into a single order (*Arthrogastra*), but they are separated by the nature of the respiratory organs, the latter breathing by tracheæ, and not by pulmonary sacs.

Sub-order 1. *Scorpiodea.*—This group includes only the true Scorpions, which are amongst the best known, as well as the largest of living *Arachnida.* The integument in the Scorpions is hardened by chitine so as to form a resisting exoskeleton, and the cephalothorax is not constricted off from the abdomen, this latter region being distinctly segmented (fig. 216, A). The cephalothorax is covered above by a shield-like or ovate plate, which bears the simple eyes, six, eight, or twelve in number, of which two large ones are placed centrally, while the remainder are marginal (fig. 216, B). The mouth opens on the under surface of the head in front, and is furnished anteriorly with an upper lip-plate or "labrum." The first pair of appendages, corresponding with the "falces" or "mandibles" of the Spiders, are the "cheliceræ," which have the form of short pincers, or nipping-claws (fig. 216, *c*). Behind the cheliceræ are the maxillæ, each of which gives rise to an immensely developed "maxillary palpus," which ends in a powerful nipping-claw or chela (fig. 216, *m*). Behind the maxillæ, closing the aperture of the mouth posteriorly, is a lower lip or "labium," which is partially divided into two by a longitudinal groove, and is thus seen to represent a second pair of maxillæ. The four segments following the labium carry the four pairs of walking-legs. The first seven segments of the abdomen (constituting the "abdomen" proper) are approximately equal in width to the cephalothorax. On the under surface of the first of these is the opening of the repro-

ductive organs, protected by an opercular plate. The next segment carries inferiorly a pair of curious serrated comb-like organs ("pectines"), which are present in both sexes, but the uses of which are unknown. The next four segments exhibit the oblique openings ("stigmata") of the pulmonary sacs (fig. 216, *s*), and the seventh segment presents no special pecu-

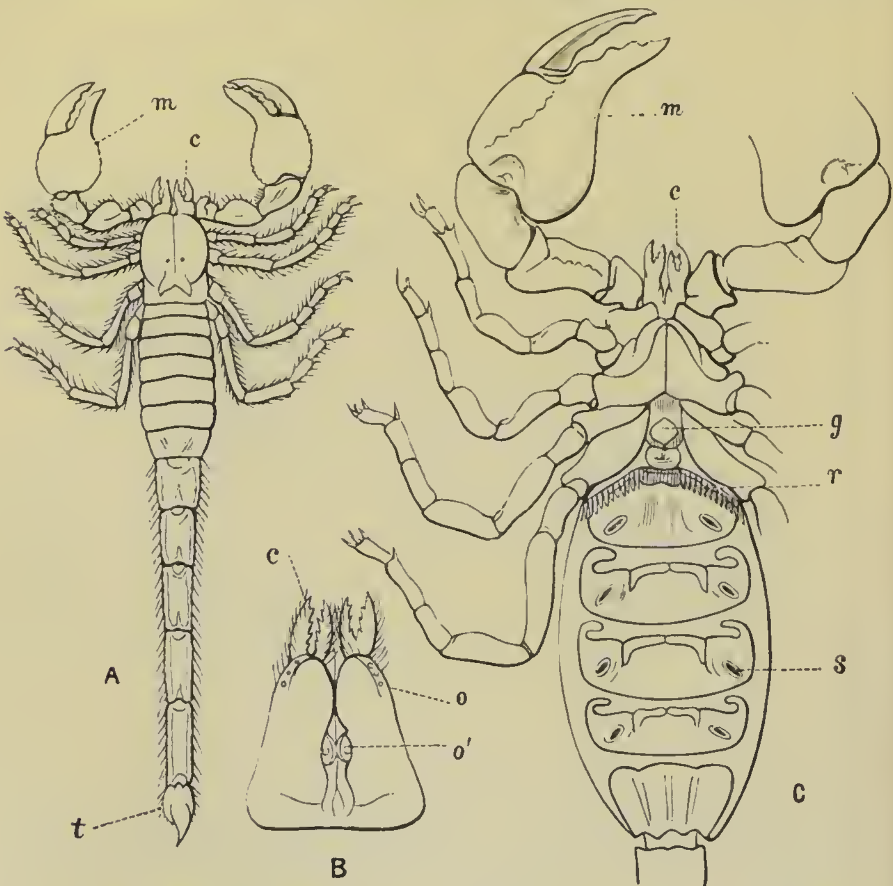

Fig. 216.—Pedipalpi. A, *Scorpio afer*, viewed from above, and somewhat reduced in size. B, Front portion of the head of the same, viewed from above, and enlarged. C, *Buthus Kochii*, with the terminal segments and the ends of the appendages on one side omitted. *m* Maxillary palpi (behind these are the four pairs of ambulatory legs); *c* Cheliceræ; *t* Telson; *o* Lateral ocelli; *o'* Central, larger ocelli; *g* Opercular plate, covering the opening of the reproductive organs; *r* one of the "combs"; *s* One of the stigmatic openings. (C is after Prof. Ray Lankester.)

liarity. Following the proper abdominal segments are six narrow somites, which constitute the "post-abdomen." The last of these is swollen at its base and hooked at its point, and contains two poison-glands, the secretion of which is discharged by minute apertures at the sharp apex of the telson.

As regards their internal anatomy, the Scorpions present noticeable peculiarities as regards their circulatory and respira-

tory organs. The heart is long and tubular, and consists of eight chambers. It is contained in a "pericardial sinus," similar to that of the Lobster, and the blood is admitted to its interior by a valvular slit in each chamber. The heart drives the arterial blood through the arteries, which end in capillaries, and the veins distribute the venous blood over the respiratory sacs, the vessels from which pour the now arterialised blood into the pericardial sinus. The respiratory organs are in the form of four pairs of respiratory chambers or lung-sacs, opening on the under surface of the 3d, 4th, 5th, and 6th abdominal segments by oblique slit-like "stigmata." Each lung-sac has the form of a compressed sac, the wall of which is thrown into a number of closely-appressed lamellar involutions like the leaves of a book, over which the venous blood is distributed for aeration.

Some of the smaller Scorpions are found in Southern Europe, but the larger forms are natives of hot countries, and may reach a length of half a foot or more. Their sting is very severe, but rarely fatal to man. The Scorpions live under stones or in dark crevices, and run swiftly, carrying the tail curved over the back. They feed on insects, which they hold in the chelate palpi, and sting to death.

The earliest-known types of the Scorpions are found in the Silurian rocks, and these extremely ancient forms show no fundamental structural differences from the modern representatives of the group.

Sub-order 2. *Phrynidea.*—The members of this group in external appearance closely resemble the true Spiders, from which they are separated by the possession of a segmented abdomen, by the slenderness and spinose character of the anterior pair of legs, and by the absence of spinnerets. They are distinguished from the *Scorpionidæ* by the amalgamation of the head and thorax into a single mass, which is clearly separated from the abdomen by a constriction, as well as by the fact that the maxillary palpi terminate in movable claws, or have only a very imperfect chela. Further, the extremity of the abdomen is not furnished with a terminal hook or "sting."

In *Thelyphonus* (fig. 215, C) the abdomen terminates in three post-abdominal segments, to which a long many-jointed caudal appendage is attached; but in *Phrynus* (fig. 217), the abdomen ends in a button-like segment. The first pair of legs is the longest (immensely so in *Phrynus*), the falces are not chelate; and the maxillary palpi, though of large size, and sometimes didactyle, do not form true chelæ. The genus

Thelyphonus is confined to the tropical parts of Asia, America, and Australia, and the genus *Phrynus* is also wholly tropical.

ORDER II. ARANEIDA or SPHÆROGASTRA.—This order in-

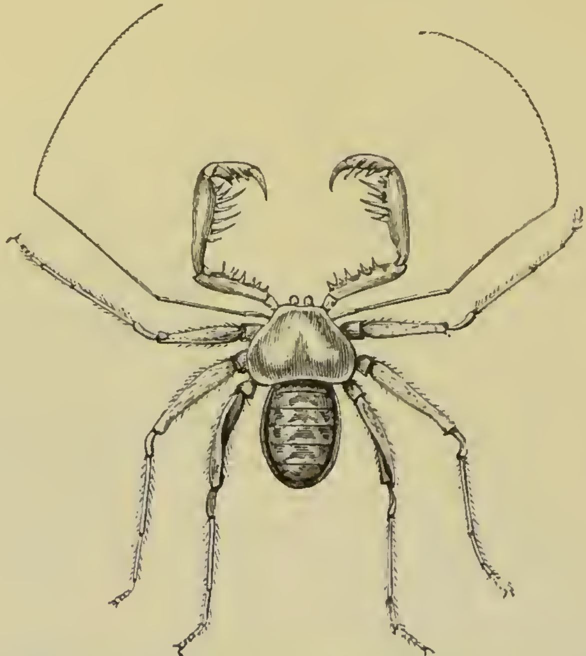

Fig. 217.—*Phrynus reniformis*, showing the long claw-like maxillary palpi, and the exceedingly slender and spinose first pair of walking-legs.

cludes the true Spiders, which are characterised *by the amalgamation of the cephalic and thoracic segments into a single mass, and by the generally soft, unsegmented abdomen, attached to the cephalothorax by a constricted portion, or peduncle. Respiration is effected by pulmonary sacs in combination with tracheæ.* (Hence the name *Pulmotrachearia*, sometimes applied to the order.)

The cephalothorax of the Spiders is covered by a horny plate, and bears in front two, four, six, or eight simple eyes (fig. 209, B). The mandibles or falces are terminated by sharp movable hooks, perforated at their apices by a minute aperture leading by a duct to a poison-gland situated in the basal part of the mandible (fig. 218, *an*). Behind the mandibles are the small maxillæ, each of which gives origin to a long jointed "maxillary palpus." In the female Spiders the maxillary palpi (fig. 218, *p*) are slender and leg-like, their extremities terminating in pointed claws. In the males, on the other hand, the maxillary palpi are swollen at their ends (fig. 218, B), and are specially modified for the purpose of

conveying the spermatozoa to the female. Behind the maxillæ is a small lower lip-plate or "labium," morphologically representing a second pair of maxillæ.

The alimentary system of the Spiders has already been briefly described (see p. 369, fig. 210). The heart consists of a tubular "dorsal vessel," which is not contained in a pericardial sinus (as it is in the Scorpions), and to which the blood is admitted by three pairs of valvular slits. The respiratory organs consist partly of pulmonary sacs and partly of tracheæ. In most Spiders (*Dipneumones*) there are only two lung-sacs, the stigmata of which are placed on the under surface of the abdomen, a little behind the point where it is connected with the cephalothorax (fig. 218, *st*). In the *Mygalidæ* (hence called *Tetrapneumones*) there are four lung-sacs. Just behind the two pulmonary stigmata, in the ordinary Spiders, are two smaller apertures which open into air-tubes or tracheæ. These consist of membranous branched tubes, the walls of which may be prevented from collapsing by a coiled-up chitinous fibre. The opening of the reproductive organs is, in both sexes, placed on the under surface of the abdomen, between the pulmonary stigmata.

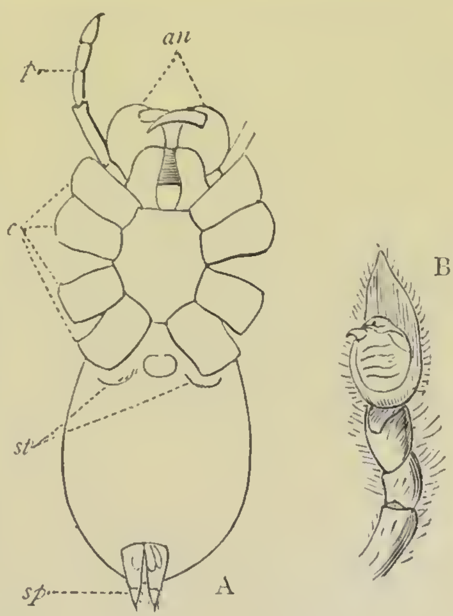

Fig. 218.—A, Under surface of a Spider (*Lycosa andrenivora*), the walking-legs having been removed with the exception of the basal joints (*c*). *an* Falces; *p* One of the maxillary palpi; *st* Stigmata, leading into the pulmonary sacs, and having the generative aperture between them; *sp* Spinnerets. B, Termination of the maxillary palpus of the male of the same, much enlarged.

All the Spiders possess spinning-glands in the form of tubular organs situated in the abdomen, and secreting a viscid fluid, which hardens rapidly on exposure to air. The excretory ducts of these glands open by fine tubular pores on the surface of the so-called "spinnerets" (fig. 218, *sp*). These are little conical or cylindrical organs, which are usually six in number (only four in the *Mygalidæ*), and are situated at the extremity of the abdomen. The viscid secretion of the silk-glands is cast into its proper thread-like shape in passing through the ducts of the spinnerets, and the

silken fibres thus produced are used by the Spider for constructing an abode for itself, for locomotion, for making a "web" in which to capture its prey, or for other purposes.

The form of the web has been employed as a basis of classification of the Spiders, and amongst its numerous modifications, the following may be specially alluded to: Some forms (such as the common Garden-spiders) construct a web in the form of an incomplete or complete circle, with lines radiating from the centre. These have been termed "*Orbitelariæ.*" Others —the so-called "*Retitelariæ*"—simply spin a thin suspended sheet for their web. Others ("*Tubitelariæ*") construct a silken tube, inserted in any accidental cavity, its mouth being open and guarded by more or fewer threads. Lastly, others ("*Territelariæ*") spin a silken tube in a hole formed by the animal itself, and close its mouth by means of a variously constructed lid.

The Spiders are oviparous, and the young pass through no metamorphosis; but they cast their skins or moult repeatedly, before they attain the size of the adult. Most Spiders deposit their eggs in silken nests or cocoons, often beautifully constructed, and sometimes carried about by the females. The males are generally smaller than the females, and of rarer occurrence. All the Spiders are predaceous in their habits, and live upon insects, which they kill by means of their poisonous bite. Very many of them are sedentary and construct a web; but others (*Vagabundæ*) lead a wandering life, making no web, but hunting their prey for themselves.

The earliest-known fossil remains of Spiders are found in the Coal-measures.

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CHAPTER XXXIII.

MYRIOPODA.

Class III. Myriopoda (or Myriapoda).—The *Myriopoda* are defined as *articulate animals in which the head is distinct, and the remainder of the body is divided into nearly similar segments, the thorax exhibiting no clear line of demarcation from the abdomen. There is one pair of antennæ, and the number of the legs is always more than eight pairs. Respiration is by tracheæ.*

In this class—comprising the Centipedes (fig. 219) and the Millepedes—the integument is chitinous, the body is divided into a number of somites provided with articulated appendages, and the nervous and circulatory organs are constructed upon a plan similar to what we have seen in *Crustacea* and *Arachnida*. The head is invariably distinct, and there is no marked line of demarcation between the segments of the thorax and those of the abdomen. The body, except in *Pauropus*, always consists of more than twenty somites, and those which correspond to the abdomen in the *Arachnida* and *Insecta* are always provided with locomotive limbs. "The head consists of at least five, and probably of six, coalescent and modified somites; and some of the anterior segments of the body are, in many genera, coalescent, and have their appendages specially modified to subserve prehension" (Huxley). *Pauropus* has only nine pairs of legs; but, with this exception, eleven pairs of legs is the smallest number known in the order.

The respiratory organs, with one exception (*i.e.*, *Pauropus*), agree with those of the *Insecta* and of many of the *Arachnida* in being "tracheæ"—that is to say, tubes, which open upon the surface of the body by minute apertures, or "stigmata," and the walls of which are strengthened by a spirally-coiled filament of chitine. The tracheæ may or may not anastomose with one another as they do in Insects.

The somites, with the exception of the head and the last

abdominal segment, are usually undistinguishable from one another, and each generally bears a single pair of limbs. In some cases, however, each segment appears to be provided

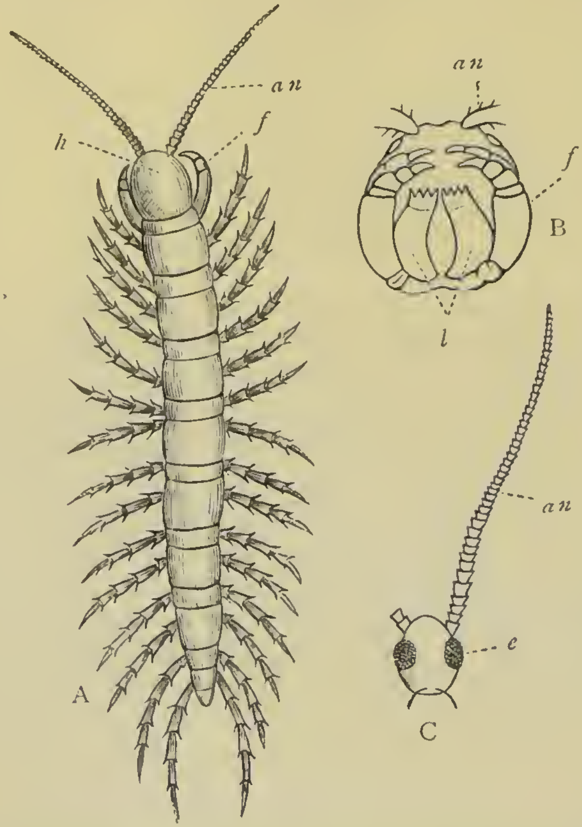

Fig. 219.—A, *Lithobius forficatus*, enlarged and viewed from above: *an* Antennæ; *f* Foot-jaws; *h* Head. B, Head of *Lithobius Leachii*, viewed from below (after Newport): *an* Antennæ; *f* Hooked foot-jaws; *l* Lower lip, composed of two pieces. C, Head of *Lithobius forficatus*, viewed from above (after Gervais): *an* Antenna; *c* Eye.

with two pairs of appendages (fig. 220). This is really due to the coalescence of the somites in pairs, each apparent segment being in reality composed of two amalgamated somites. This is shown, not only by the bigeminal limbs, but also by the arrangement of the stigmata, which in the normal forms occur on every alternate ring only, whereas in these aberrant forms they are found upon every ring.

The head always bears a pair of jointed antennæ, resembling those of many Insects, and behind the antennæ there is generally a variable number of simple sessile eyes. In one genus (*Scutigera*) compound facetted eyes are present; and in *Pauropus* the antennæ are bifid, and carry many-jointed

appendages, thus differing wholly from the antennæ of Insects, and presenting a decided approximation to those of the *Crustacea.*

The young in some cases, on escaping from the egg, possess nearly all the characters of the parents, except that the number of somites, and consequently of limbs, is always less, and increases at every change of skin ("moult" or "ecdysis"). In most cases, however, there is a species of metamorphosis, the embryo being at first possessed of no more than three pairs of legs, thus resembling the true Insects. In some other cases the larva has at first seven pairs of legs. In these cases the number of legs proper to the adult is not obtained until after several moults, the entire process being stated to occupy in some species as much as two years, before maturity is reached.

As regards their *distribution in time*, the earliest known types of the *Myriopoda* occur in the Devonian (Old Red Sandstone), and the order is largely represented in the Carboniferous period. According to the most recent investigators, all the Palæozoic Myriopods belong to sections of the class which have no modern representatives, and their characters need not be discussed here. Of the living orders of Myriopods, the Centipedes (*Chilopoda*) do not seem to have come into existence earlier than the Tertiary period, and the Millepedes (*Chilognatha*) are only dubiously represented in rocks of Secondary age by one Cretaceous form.

The *Myriopoda* are divided into three orders—viz., the *Chilopoda*, the *Chilognatha*, and the *Pauropoda*, to which a fourth, under the name of *Onychophora*, may be provisionally added for the reception of the aberrant genus *Peripatus.*

ORDER I. CHILOPODA.—This order comprises the well-known carnivorous Centipedes and their allies, and is characterised by the number of legs being rarely indefinitely great (usually from 15 to 20 pairs), by the composition of the antennæ out of not less than 14 joints (14 to 40 or more), and by the structure of the mouth-organs. These consist of a pair of "mandibles," representing the mandibles of Insects, and a pair of small jointed maxillæ, which are partially united in the middle line. The segment immediately behind the head (the so-called "basilar segment") is really composed of four somites fused together, and it carries two pairs of foot-jaws or maxillipedes, of which the first pair are slender and leg-like, while the second pair are of large size, and are terminated by perforated hooks which communicate with internally-placed poison-glands (fig. 219, *f*). Behind the poison-

fangs the basilar segment carries a pair of small jointed legs, which are sometimes rudimentary or wanting.

The remaining somites carry each a pair of jointed legs, the last pair of which are often directed backwards in the axis of the body, so as to form a kind of tail. The segments are flattened, and each is protected by a horny plate (tergum) superiorly, and a corresponding plate (sternum) on the ventral surface. The stigmata are placed on the sides of the body, usually on alternate segments. The generative apertures are placed at the posterior end of the body.

All the *Chilopoda* are carnivorous and nocturnal in their habits. The genera *Scolopendra*, *Lithobius* (fig. 219), and *Geophilus*, are all represented in Europe by more or less familiar types. The *Geophili* are devoid of eyes, and have very slender bodies and numerous legs. In tropical countries, the Centipedes often attain a length of from six inches to a foot, and are capable of inflicting very severe or even dangerous wounds by means of their great poison-fangs.

ORDER II. CHILOGNATHA.—This order comprises the vegetable-eating Millepedes (*Julidæ*), the Galley-worms (*Polydesmus*), and other allied forms. The order is characterised by the great number of legs — each segment, except some of the

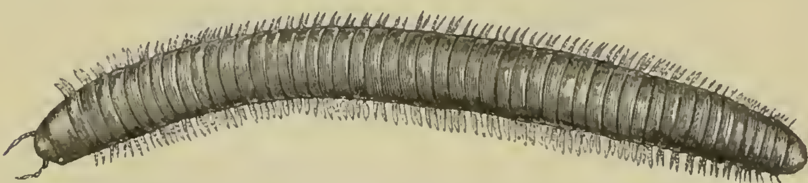

Fig. 220.—Millepede (*Iulus maximus*), a small example, of the natural size.

anterior ones, bearing two pairs—by the composition of the antennæ out of six or seven joints; and by the structure of the masticating organs, which consist of a pair of mandibles without palps, covered by a lower lip composed of the confluent maxillæ.

The body in the *Chilognatha* is usually cylindrical, though depressed in *Polydesmus*. The three somites which follow the head (thoracic segments) are not fused as they are in the Chilopods, and they carry only a single pair of legs. The remaining segments (with the occasional exception of the two or three foremost ones) carry each two pairs of minute jointed legs. Each apparent segment may, therefore, be regarded as in reality formed by the fusion of two somites. The seventh somite of the males is furnished with a pair of copulatory organs, and wants one or both of the pairs of legs. The

openings of the generative organs are placed at the base of the second or third pair of legs. Each apparent segment carries a pair of stigmata, placed close to the bases of the legs. The animal is also often furnished with cutaneous glands, which secrete an acrid fluid, and open by serially-placed dorsal pores.

All the *Chilognatha* feed on decaying organic matter, and the typical genus is *Iulus* (fig. 220), comprising the ordinary Millepedes. These have a long cylindrical body of many segments, and when alarmed, coil themselves into a flat spiral. The European Millepedes are comparatively small; but some tropical species attain a length of half a foot or more. The "Pill-Millepedes" (*Glomeris*) are like short *Iuli*, and they protect themselves by rolling themselves into a ball.

ORDER III. PAUROPODA.—This order was established by Sir John Lubbock for the reception of a single generic type to which he gave the name of *Pauropus*. The body in *Pauropus Huxleyi* (fig. 221) is only $\frac{1}{20}$th of an inch in length, and consists of ten somites, furnished with scattered setæ. There are only nine pairs of legs, of which one pair is carried by the 3d segment, whilst the 4th, 5th, 6th, and 7th segments carry each two pairs of legs, and may therefore be regarded as really double. The head is composed of two segments, and is not provided with jaw-feet. The antennæ are five-jointed, bifid, with three long multiarticulate appendages. The body is white and colourless, and there are no tracheæ, so that respiration must be effected entirely by the skin. *Pauropus* is found amongst decaying leaves in damp situations, and species have been described both from Britain and America. It is separated from the *Chilopoda* by its small number of legs, the absence of foot-jaws, and the composition of the antennæ out of no more than five joints.

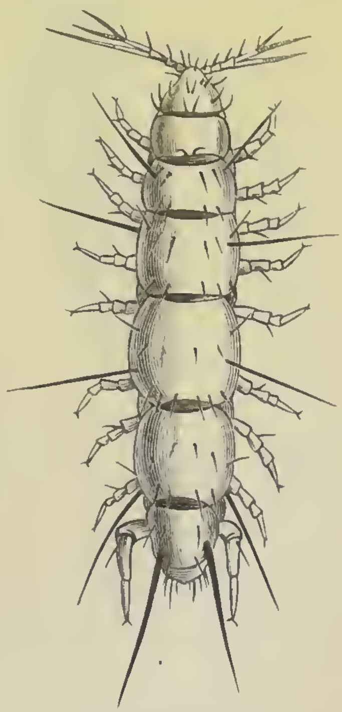

Fig. 221.—*Pauropus Huxleyi*, viewed from above, and enlarged fifty diameters. (After Sir John Lubbock.)

ORDER IV. ONYCHOPHORA (Grube).—In the West Indies,

South Africa, South America, and New Zealand occur examples of a peculiar genus of animals, which has been named *Peripatus*, and has been at different times referred to the Errant Annelides, the Leeches, the Scolecids, or the *Myriopoda*. The species of *Peripatus* are terrestrial in their habits, living in moist earth, in decayed wood, or under stones, active by night only, and completely worm-like in form. The cylindrical body (figs. 222, A, and 223) is annulated, and

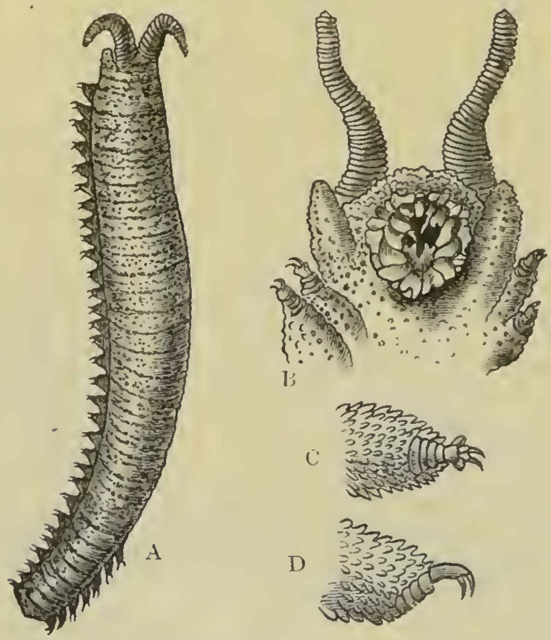

Fig. 222.—A, *Peripatus Edwardsii*, magnified two diameters. B, Head, viewed from below, enlarged five times. C and D, A single foot, viewed from above and sideways, enlarged. (After Grube.)

provided with numerous pairs of ambulatory feet, which are jointed, and terminated by one or two hooked claws (fig. 222, C and D), sometimes with a bunch of setæ. The animal walks like a caterpillar, by means of its feet, and rolls up like a Millepede when alarmed. The head carries a pair of antennæ and two simple eyes.

The mouth in *Peripatus* (fig. 222, B) is placed below the head, and is furnished with a pair of horny hooked jaws. The alimentary canal is straight, and the anus is placed at the end of the body. The respiratory system consists of tracheæ, which, as shown by Moseley, exhibit the unique feature that their external openings (the "stigmata") are irregularly distributed over the whole surface of the body. The arrangement of the nervous system is equally remarkable in the fact that

the ventral nerve-cords do not coalesce, but remain widely separate, and are not furnished with ganglia corresponding with the successive segments of the body. A third remarkable structural feature is the presence of successive pairs of organs, which open externally at the bases of the legs, and communicate with the body-cavity, and which appears to correspond with the segmental organs of the *Annelida*. The sexes

Fig. 223.—Onychophora. *Peripatus capensis*. (After Moseley.)

appear to be sometimes distinct, sometimes united, in different species; and the young are brought forth alive.

In many respects *Peripatus* occupies a position intermediate between the Annelides on the one hand, and the air-breathing Arthropods on the other hand. Among the latter, its relationships appear to be closest with the Myriopods; but its structural peculiarities are so many and so remarkable, that it is often considered as the representative of a distinct *class*, for which the name of *Protracheata* has been proposed.

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CHAPTER XXXIV.

INSECTA.

GENERAL CHARACTERS OF THE INSECTA.

CLASS IV. INSECTA.—The *Insecta* are defined as *Articulate animals in which the head, thorax, and abdomen are distinct; there are three pairs of legs borne on the thorax; the abdomen is destitute of legs; a single pair of antennæ is present; mostly, there are two pairs of wings on the thorax. Respiration is effected by tracheæ.*

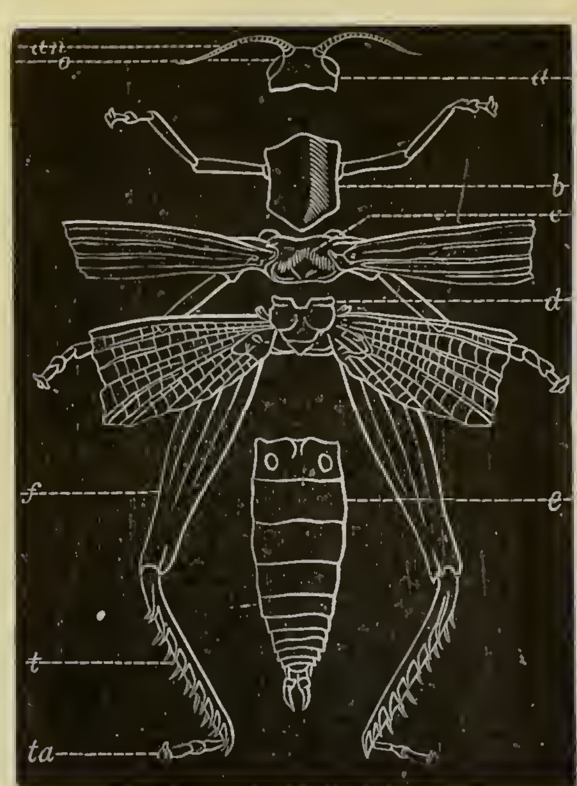

Fig. 224.—Diagram of the external anatomy of an Insect. *a* Head carrying the eyes (*o*) and antennæ (*an*); *b* First segment of the thorax, with the first pair of legs; *c* Second segment of the thorax, with the second pair of legs and the first pair of wings; *d* Third segment of the thorax, with the third pair of legs and the second pair of wings; *e* Abdomen, without limbs, but carrying terminal appendages concerned in reproduction; *f* Femur; *t* Tibia; *ta* Tarsus.

In the *Insecta* the body is divided into a variable number of definite segments, or somites, some of which are furnished with jointed appendages, and the nervous and circulatory systems are constructed upon essentially the same plan as in the *Crustacea*, *Arachnida*, and *Myriopoda*. The head, thorax, and abdomen are distinct (figs. 224, 225), and the total number of somites in the body never exceeds twenty. "Of these, five certainly, and six probably" (according to most authorities, four only), "constitute the head, which possesses a pair of antennæ, a pair of mandibles, and two pairs of maxillæ, the hinder pair of which are coalescent, and form the 'labium.' Three, or perhaps, in some cases, more, somites

unite and become specially modified to form the thorax, to which the three pairs of locomotive limbs, characteristic of perfect Insects, are attached. Two additional pairs of locomotive

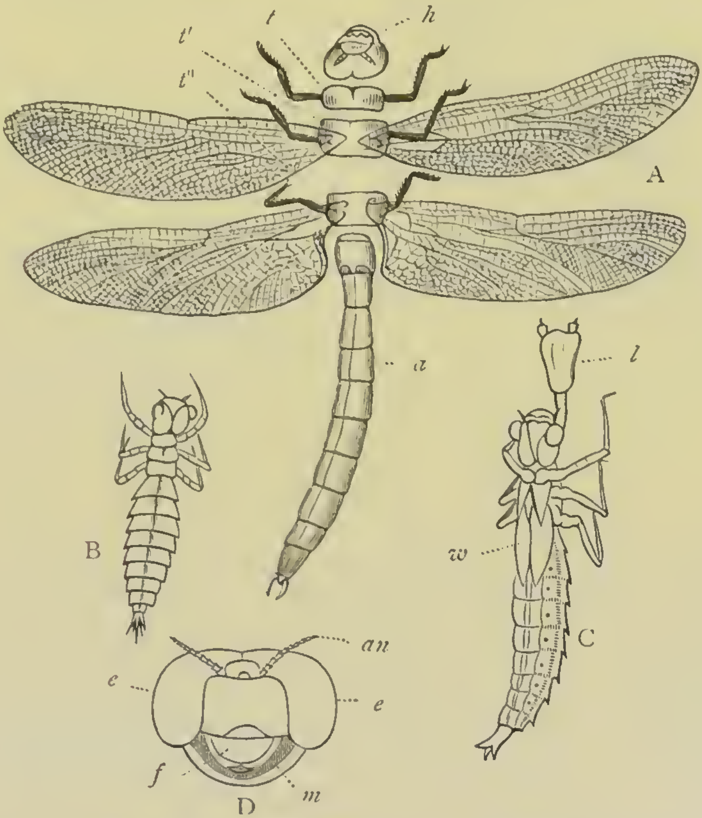

Fig. 225.—A, One of the Dragon-flies (*Æshna grandis*), slightly dissected: *h* Head, carrying the eyes, antennæ, and organs of the mouth; *t t' t''* First, second, and third segments of the thorax slightly separated from one another, each carrying a pair of legs, and the two last carrying each a pair of wings; *a* Abdomen. B, Young form, or "larva," of the same. C, Second stage, or "pupa." D, Head of a Dragon-fly (*Libellula depressa*), showing the feelers or antennæ (*an*), the eyes (*e e*), the hinder pair of jaws (*m*), and the upper lip (*f*).

organs, the wings, are developed, in most insects, from the tergal walls of the second and third thoracic somites. No locomotive limbs are ever developed from the abdomen of the adult insect; but the ventral portions of the abdominal somites, from the eighth backwards, are often metamorphosed into apparatuses ancillary to the generative function" (Huxley).

The integument of the *Insecta*, in the mature condition, is more or less hardened by the deposition of chitine, and usually forms a resisting exoskeleton, to which the muscles are attached. The four segments of the head are amalgamated

into a single piece, which bears a pair of jointed feelers or antennæ, a pair of eyes, usually compound, and the appendages of the mouth. The segments of the thorax are also amalgamated into a single piece; but this, nevertheless, admits of separation into its constituent three somites (figs. 224, 225). These are termed respectively, from before backwards, the "prothorax," "mesothorax," and "metathorax," and each bears a pair of jointed legs. In the great majority of Insects, the dorsal arches of the mesothorax and metathorax give origin each to a pair of wings.

Each leg consists of from six to nine joints (see fig. 228). The first of these, which is attached to the sternal surface of the thorax, is called the "coxa," and is succeeded by a short joint, termed the "trochanter." The trochanter is followed by a joint, often of large size, called the "femur," succeeded by the so-called "tibia," and this has articulated to it the "tarsus," which may be composed of from one to five joints.

The wings of Insects are expansions of the sides of the meso- and meta-thorax, these expansions being supported by slender but firm tubes, known as the "nervures." Each nervure consists of a central trachea or air-tube, running in the centre of a larger blood-tube; so that the wings not only act as organs of flight, but at the same time assist in the process of respiration. Normally, two pairs of wings are present, but one or other may be wanting. In the *Coleoptera* (Beetles) the anterior pair of wings become hardened by the deposition of chitine, so as to form two protective cases for the hinder membranous wings. In this condition the anterior wings are known as the "elytra," or "wing-cases." In some of the *Hemiptera* this change only affects the inner portions of the anterior wings, the apices of which remain membranous, and to these the term "hemelytra" is applied. In the *Diptera* the posterior pair of wings are rudimentary, and are converted into two capitate filaments, called "halteres" or "balancers." In the *Strepsiptera* the anterior pair of wings are rudimentary, and are converted into twisted filaments.

The typical number of somites in the abdomen of the *Insecta* is ten or eleven, and this number can sometimes be recognised in the *Orthoptera* and some other forms. In the *Hymenoptera* and *Lepidoptera* not more than nine or ten can be recognised, and in many cases even fewer can be made out. The abdominal somites are usually more or less freely movable upon one another, and never carry locomotive limbs. The extremity of the abdomen is, however, commonly furnished with appendages, which are connected with the gen-

erative function, and not infrequently serve as offensive and defensive weapons. Of this nature are the ovipositors of Ichneumons and other insects, and the sting of Bees and Wasps. In the Earwig (*Forficula*) these caudal appendages form a pair of forceps; whilst in many insects they are in the form of bristles, by which powerful leaps can be effected, as is seen in the Spring-tails (*Poduræ*). In some insects (as the Mole-cricket and the male Cockroach), one of the hindmost abdominal segments carries jointed antenniform appendages, which, though perhaps partially or even primarily generative in function, are certainly organs of sense, being connected with smell or hearing.

The organs of the mouth in Insects are collectively termed the "trophi," or "instrumenta cibaria." Two principal types require consideration—namely, the masticatory and the suctorial—both types being sometimes modified, and occasionally combined.

In the Masticatory Insects, such as the Beetles (fig. 226, A),

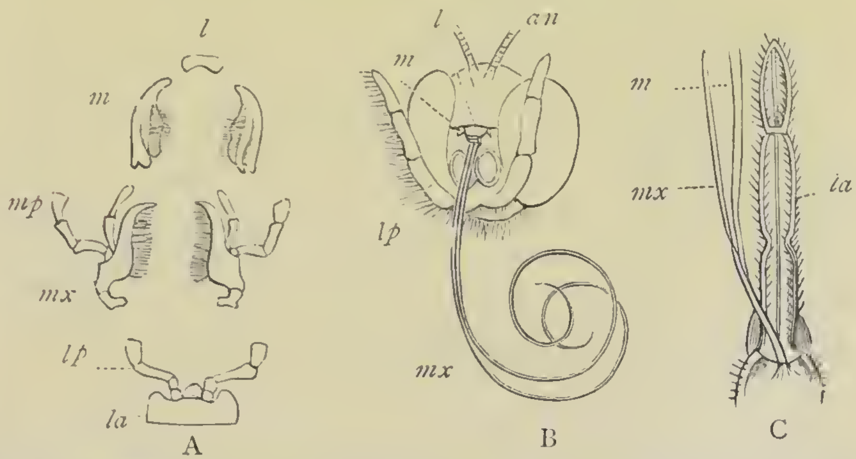

Fig. 226.—Organs of the mouth of Insects, enlarged, (A) of a Beetle (*Carabus*), (B) of the small Cabbage White Butterfly (*Pontia rapæ*); (C) of the Bed-bug (*Cimex lectularius*), the mandibles and maxillæ being displaced to one side. *l* Labrum; *m* Mandible; *mx* Maxilla; *mp* Maxillary palpus; *la* Labium; *lp* Labial palpus; *an* Base of one of the antennæ. (Fig. B is slightly altered from Westwood.)

the trophi consist of the following parts, from before backward: 1. An upper lip, or "labrum," attached below the front of the head; 2. A pair of biting-jaws, or "mandibles," without palps; 3. A pair of chewing-jaws, or "maxillæ," provided with one or more pairs of "maxillary palps," or sensory and tactile filaments; 4. A lower lip, or "labium," composed of a second coalescent pair of maxillæ, and also bearing a pair of palpi, the "labial palps." The primitive form of the

labium—that, namely, of a second pair of maxillæ—is more or less perfectly retained by the *Orthoptera* and some of the *Neuroptera*. The lower or basal portion of the labium is called the "mentum," or chin, whilst the upper portion is more flexible, and is termed the "ligula." The central portion of the ligula is often developed into a kind of tongue, which is very distinct in some Insects (as in Bees), and is termed the "lingua," while its lateral portions may be developed as special organs termed "paraglossæ."

In the typical suctorial mouth, as seen in the Butterflies (fig. 226, B), the following is the arrangement of parts: The labrum and the mandibles are now quite rudimentary, and the first pair of maxillæ is greatly elongated, each maxilla forming a half-tube. The maxillæ adhere together by their inner surfaces, and thus form a spiral "trunk," or "antlia" (inappropriately called the "proboscis") by which the juices of flowers are sucked up. To the base of the trunk are attached the maxillary palpi, which are extremely small. Behind the trunk is a small labium, composed of the united second pair of maxillæ. The "labial palpi" are greatly developed, and form two hairy cushions, between which the trunk is coiled up when not in use.

In the Bee there exists an intermediate condition of parts, the mouth being fitted partly for biting, and partly for suction. The labrum and mandibles are well developed, and retain their usual form. The maxillæ and the labium are greatly elongated; the former being apposed to the lengthened tongue in such a manner as to form a tubular trunk, which cannot be rolled up, as in the Butterflies, but is capable of efficient suction. The labial palpi are also greatly elongated.

In the *Hemiptera*, the "trophi" consist of four lancet-shaped needles, which are the modified mandibles and maxillæ, enclosed in a tubular sheath formed by the elongated labium (fig. 226, C). Lastly, in the *Diptera*—as in the common House-fly—there is an elongated labium, which is channelled on its upper surface for the reception of the mandibles and maxillæ, these being modified into bristles or lancets.

The mouth in Insects opens into a gullet (fig. 227, *a*), to which is appended a pair (or two pairs) of salivary glands, furnished often with a capacious "salivary receptacle" on each side. The hinder portion of the œsophagus is dilated into a membranous sac or "crop" (fig. 227, *b*), often of great size. From the crop the food passes into a muscular division of the stomach, which is known as the "gizzard" or "proventricle." The gizzard is adapted for crushing, plates or teeth of chitine

being developed in its walls. It is succeeded by a longer division of the stomach, the lining of which is glandular, and which is known as the "chylific stomach," or "*ventriculus chylopoieticus*" (fig. 227, *d*). Digestion is carried on here, and the commencement of the chylific stomach is sometimes furnished with a circle of blind tubes, which appear to represent a liver. From the chylific stomach proceeds an intestine of variable length, which terminates in a dilated "cloaca" (fig. 227, *g*). Behind the chylific stomach is a variable number of cæcal convoluted tubes (fig. 227, *e*) which open into the commencement of the intestine, and which are known as the "Malpighian tubes." There are usually four or six Malpighian vessels, and their function is undoubtedly excretory, so that they correspond with the kidneys of the higher animals. The "silk-glands," which are present in the larvæ of Insects, are large tubular organs contained in the abdomen, and they may be regarded as modified salivary glands. They open by a projecting tubular aperture (the "spinneret") placed upon the labium. Rarely (in *Myrmeleo*) there are silk-glands opening in the abdominal region. There are no absorbent vessels, and the products of digestion simply transude through the walls of the alimentary canal into the sinuses or irregular cavities which exist between the abdominal organs. The apparatus of digestion does not differ essentially from the above in any of the Insects; but the alimentary canal is, generally speaking, considerably lengthened in the herbivorous species.

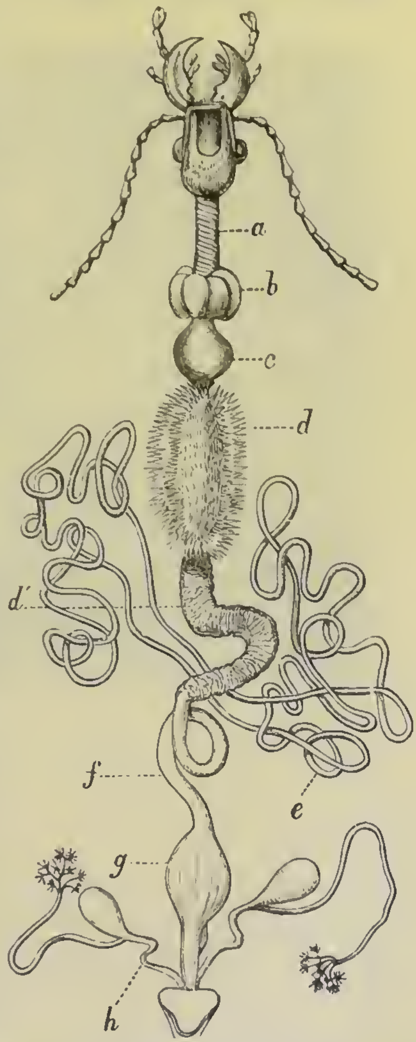

Fig. 227.—Alimentary canal of a Beetle (*Carabus auratus*). *a* Œsophagus; *b* Crop; *c* Gizzard; *d* Wide portion of chylific stomach; d' Narrow portion of the chylific stomach; *e* Malpighian tubes; *f* Intestine; *g* Cloaca; *h* Anal glands. (After Dufour.)

There is no absolutely definite course of the circulation in the Insects. The propulsive organ of the circulation is a long contractile cavity, situated dorsally and termed the "dorsal vessel" (fig. 228, *h*). This is composed of a number of sacs

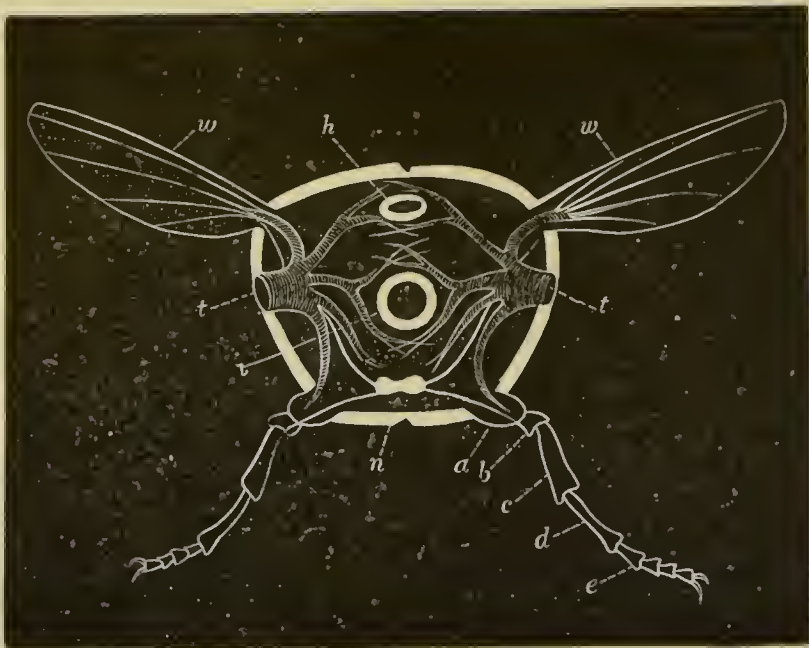

Fig. 228.—Ideal transverse section of an Insect. *h* Dorsal vessel; *i* Intestine; *n* Ventral nerve-cord; *t t* Stigmata, leading into the branched tracheal tubes; *w w* Wings; *a* Coxa of one leg; *b* Trochanter; *c* Femur; *d* Tibia; *e* Tarsus. (After Packard.)

(ordinarily eight), opening into one another by valvular apertures, which allow of a current in one direction only—viz., towards the head. The blood is collected from the irregular venous sinuses which are formed by the lacunæ and interstices between the tissues, and enters the dorsal vessel from behind, and by lateral valvular openings; it is then driven forwards, and is expelled at the anterior extremity of the body. The blood of the *Insecta* is corpusculated, and usually colourless. Whilst the general belief is that there is no regular system of blood-vessels (arteries and veins), and that the blood simply circulates through the interstices of the tissues, some observers affirm the partial existence of true vessels, and others maintain that the blood circulates in the spaces between the tracheæ and their enveloping sheaths, which thus become converted into blood-vessels.

Respiration is effected by means of "tracheæ," or branched tubes, which commence at the surface of the body by lateral apertures, called "stigmata," or "spiracles," and ramify through

every part of the animal. In structure the tracheæ are membranous, but their walls are strengthened by a chitinous filament, which is rolled up into a continuous spiral coil. In many cases the tracheæ are connected with membranous dilatations or "tracheal vesicles," which are distributed in the thorax and abdomen, and serve as air-receptacles. The walls of these tracheal vesicles are not supported by an internal coiled fibre. The renovation of the air in the tracheal system is effected by the movements of the abdominal segments. The wings, also, whilst acting as organs of locomotion, doubtless subserve respiration, the nervures being hollow tubes filled with blood and enclosing tracheæ. In the aquatic larvæ of such insects as the May-flies and Caddis-flies, the body is furnished with variously-shaped lateral outgrowths, which are richly supplied with tracheæ, and are known as "tracheal gills"; and it is by these organs that respiration is carried on. In many of the Dragon-flies the walls of the terminal portion of the intestine are supplied with tracheæ, and water is pumped in and out of the rectum, the function of respiration being thus discharged. With very rare exceptions (*e.g.*, in the Orthopterous genus *Pteronarcys*), the tracheal gills are purely larval structures, and disappear when maturity is attained.

The so-called "fat body" of Insects is an accumulation of fatty matter in lobulated masses, which lie between the body-wall and the viscera, and occupy the spaces between the latter. The fat body is especially developed in the larva towards the full period of its growth, and is used by the insect as a store of nutriment in its pupal stage, and in the formation of the reproductive organs.

The nervous system in Insects, though often concentrated into special masses, consists essentially of a chain of ganglia, placed ventrally, and united together by a series of double cords or commissures. The cephalic or "præ-œsophageal" ganglia are of large size, and distribute filaments to the eyes and antennæ. The first post-œsophageal ganglia are united to the preceding by cords which form a collar round the gullet, and they supply the nerves to the mouth, whilst the next three ganglia furnish the nerves to the legs and wings. In larvæ, thirteen pairs of ganglia may often be recognised. In the adults, however, of the higher groups of Insects (such as the *Coleoptera*, *Hymenoptera*, *Diptera*, and *Lepidoptera*), the thoracic ganglia coalesce into a single mass, while the abdominal ganglia may be similarly fused with one another.

The organs of sense are the eyes and antennæ. The eyes in Insects are usually "compound," and are composed of a

number of hexagonal lenses, united together, and each supplied with a separate nervous filament. Besides these, simple eyes—"ocelli," or "stemmata,"—are often present, or, in rare cases, may be the sole organs of vision. In structure these resemble the single elements of the compound eyes. In a few cases the eyes are placed at the extremities of stalks or peduncles, but in no case are these peduncles movably articulated to the head, as is the case in the Podophthalmous Crustaceans. The antennæ are movable, jointed filaments, attached usually close to the eyes, and varying much in shape in different Insects. They doubtless discharge the functions of tactile organs, but are probably the organ of other more recondite senses in addition.

The sexes of Insects are in different individuals, and the males and females often exhibit markedly different characters. The generative organs of the female consist of two ovaries, each of which is composed of a greater or less number of ovarian tubes. Each ovary possesses a Fallopian tube, and the two Fallopian tubes open into a common oviduct, which in turn opens by the intervention of a short vagina on the surface. Appended to the oviduct are tubular glands ("colleterial glands"), the glutinous secretion of which invests the eggs in their passage outwards, often uniting them into chains or masses, or serving to cement them to foreign bodies. Appended also to the oviduct there is usually a vesicular receptacle (the "spermatheca"), the function of which is to store up the semen of the male at the time of impregnation, so that the female can thereafter continue to impregnate the successively produced ova for a longer or shorter period. The male organs consist of a pair of testes with vasa deferentia, opening into a common ejaculatory duct, the termination of which is furnished with a copulatory organ. There are also usually accessory glands, the function of which is to form the spermatozoa into packages or "spermatophores."

Though hermaphroditism does not occur among Insects (except as an abnormality), the generative organs are not invariably developed, or may be incompletely developed, in some individuals. Thus among Social Insects, the community not only consists of males and females, but also of "neuters," or individuals in which the reproductive organs are incomplete. In Bees, Wasps, &c., the "neuters" are simply imperfectly developed females, but in the case of the White Ants they are of no fully developed sex.

While sexual reproduction is the rule among Insects, non-sexual reproduction also takes place occasionally. The par-

thenogenetic reproduction of the Honey-bee and of Aphides has been previously alluded to. (See Introduction.) There are also cases in which the larval insect has the power of reproducing itself, while its reproductive organs are still undifferentiated.

Generally speaking, the young insect is very different in external characters from the adult, and it requires to pass through a series of changes, which constitute the "metamorphosis," before attaining maturity. In some Insects, however, there appears to be no metamorphosis, and in some the changes which take place are not so striking or so complete as in others. By the absence of metamorphosis, or by the degree of its completeness when present, Insects are divided into sections, called respectively *Ametabola*, *Hemimetabola*, and *Holometabola*, which, though not, perhaps, of a very high scientific value, are nevertheless very convenient in practice.

Section 1. *Ametabolic Insects.*—These pass through no metamorphosis, and also, in the mature condition, are destitute of wings. The young of these insects (*Aptera*) on escaping from the ovum resemble their parents in all respects except in size; and though they change their skins frequently, they undergo little alteration before reaching the perfect condition, except that they grow larger.

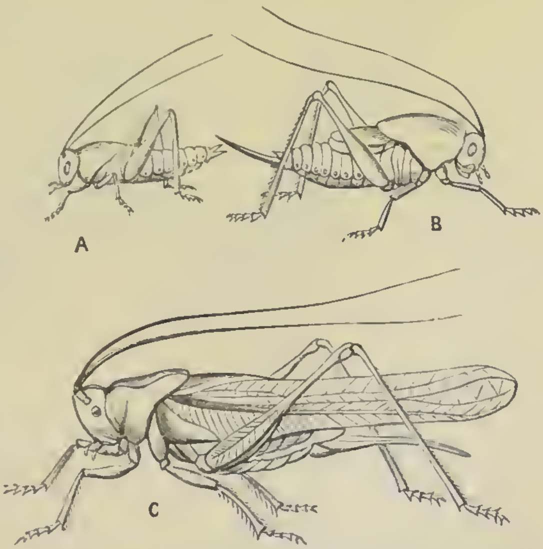

Fig. 229.—Different stages in the metamorphosis of a Grasshopper. A, Larva; B, Pupa, with the rudimentary wings; C, Adult or imago, with the fully-developed wings.

Section 2. *Hemimetabolic Insects.* — In the insects belonging to this section there is a metamorphosis consisting of three stages. The young on escaping from the ovum is termed the "larva"; when it reaches its second stage it is called the "pupa," or "nymph"; and in its third stage, as a perfect insect it is called the "imago." In the *Hemimetabola*, the "larva," though of course much smaller than the adult, or "imago," differs from it in little else except in the absence of wings. It is active and locomotive, and is generally very like the adult in external appearance (fig. 229, A). The

"pupa," again, is a little larger than the larva, but really differs from it in little else than in the fact that the rudiments of wings have now appeared, in the form of lobes enclosed in cases. The "pupa" is still active and locomotive, and the term "nymph" is usually applied to it. The pupa is converted into the perfect insect, or "imago," by the liberation of the wings and the development of the reproductive organs. From the comparatively small amount of difference between these three stages, and from the active condition of the pupa, this kind of metamorphosis is said to be "incomplete."

In some members of this section, however—such as the Dragon-flies—the larva and pupa are aquatic, whereas the imago leads an aerial life. In these cases (fig. 225) there is necessarily a considerable difference between the larva and the adult; but the larva and pupa are closely alike, and the latter is active.

Section 3. *Holometabolic Insects.* — These — comprising the Butterflies, Moths, Beetles, &c.—pass through three stages which differ greatly from one another in appearance, the metamorphosis, therefore, being said to be "complete." In these insects (fig. 230) the "larva" is vermiform, segmented, and usually provided with locomotive feet, which do not correspond with those of the adult, though these latter are usually present as well. In other cases the larva is destitute of legs, or is "apodal." The larva is also provided with masticatory organs, and usually eats voraciously. In this stage of the metamorphosis the larvæ constitute what are usually called "caterpillars" and "grubs." Having remained in this condition for a longer or shorter length of time, and having undergone repeated changes of skin, or "moults," necessitated by its rapid growth, the larva passes into the second stage, and becomes a "pupa." The insect is now perfectly quiescent, unless touched or otherwise irritated, is incapable of changing its place, and is often attached to some foreign object. This constitutes what—in the case of the *Lepidoptera*—is generally known as the "chrysalis," or "aurelia" (fig. 230). The body of the pupa is usually covered by a chitinous pellicle, which closely invests the animal. In some cases (*e.g.*, in many Dipterous insects) no traces of the future insect can be detected in the pupa by external inspection; but in the *Lepidoptera* the thorax and abdomen are distinctly recognisable in the pupæ; whilst in others (*e.g.*, *Hymenoptera*) the parts of the pupa are merely covered by a membrane, and are quite distinct. In some cases the pupa is further pro-

tected within the dried skin of the larva; and in other cases the larva—immediately before entering upon the pupa-stage—spins, by means of special organs for the purpose, a protective case, which surrounds the chrysalis, and is termed the "cocoon."

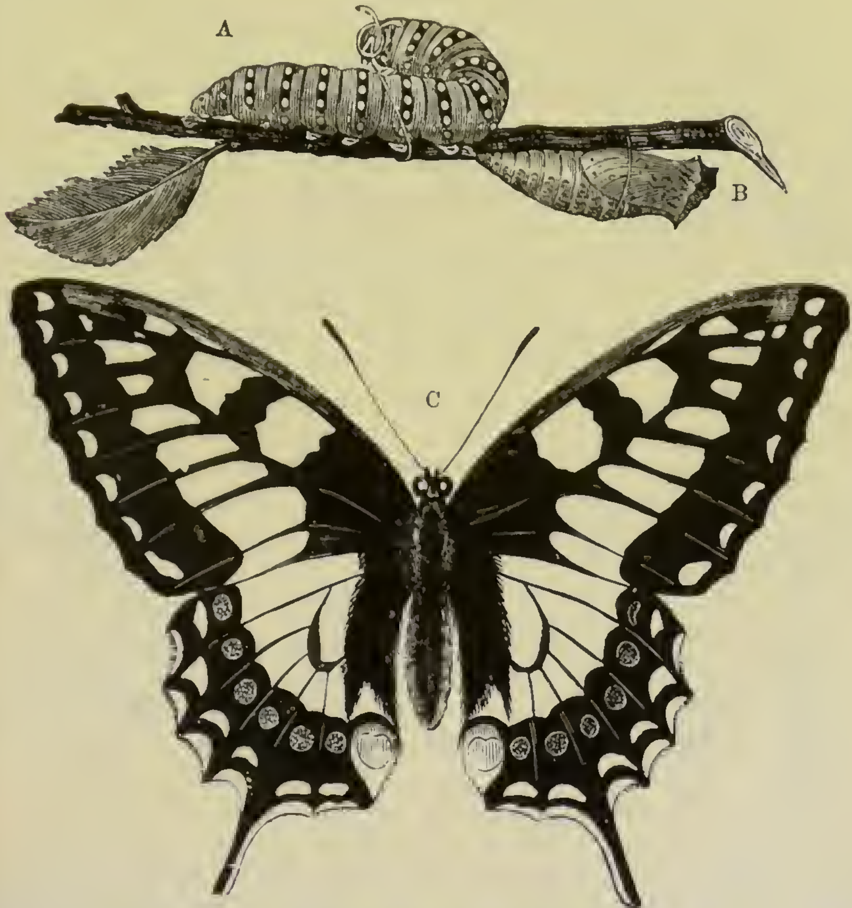

Fig. 230.—Metamorphosis of the Swallow-tail Butterfly (*Papilio machaon*). A, Larva; B, Pupa or chrysalis; C, Imago.

Having remained for a variable time in the quiescent pupa-stage, and having undergone the necessary development, the insect now frees itself from the envelope which obscured it, and appears as the perfect adult, or "imago," characterised by the possession of wings.

As regards their *distribution in space*, it is impossible to say much, for the simple reason that Insects have a cosmopolitan range, and there are but few situations in nature in which they may not be found.

By far the larger number of Insects, during their adult con-

dition, are terrestrial or aerial in their habits, but in many cases, even among these, the larvæ are aquatic. Many other insects live habitually during all stages of their existence in fresh water. A few insects inhabit salt water (either the sea itself or inland salt waters) during the whole or a portion of their existence. (This is the case with two or three Beetles of the families *Hydrophilidæ* and *Dytiscidæ*, some Hemipterous Insects, and the larvæ of various *Diptera.*) Lastly, many insects live parasitically upon the bodies of Birds or Mammals, or upon other Insects, while many others are parasitic upon plants.

As regards their *distribution in time*, the earliest known remains of insects occur in the Silurian rocks, and a comparatively considerable number of fossil Insects are known from the succeeding Devonian and Carboniferous formations. All the known Palæozoic Insects, so far as completely investigated, belong to an extinct division of Insects for which the name of *Palæodictyoptera* has been proposed, and which contains forms representative of the existing orders of the *Orthoptera*, *Hemiptera*, *Neuroptera*, and *Coleoptera*. All the recent orders just mentioned, with the addition of the orders of the *Diptera* and *Lepidoptera*, are, however, represented in rocks of Mesozoic age.

CHAPTER XXXV.

DIVISIONS OF INSECTA.

The class *Insecta* includes such an enormous number of species, genera, and families, that it would be impossible to treat of these satisfactorily otherwise than in a treatise especially devoted to entomology. Here it will be sufficient to give simply the differential characters of the different orders, drawing attention occasionally to any of the more important points in connection with any given family.

As already said, the *Insecta* are divided into three divisions, termed *Ametabola*, *Hemimetabola*, and *Holometabola*, according as they attain the adult condition without passing through a metamorphosis, or have an incomplete or complete metamorphosis. The Insects which come under the first head (viz., *Ametabola*) are not furnished with wings in the adult condition, and the four orders which compose this section are commonly

grouped together under the name *Aptera*. By some, however, this division is entirely rejected, and the orders in question are placed amongst the *Hemimetabola*, or even grouped with the *Myriopoda*. Indeed, it is certain that the orders of the so-called Apterous Insects are not, strictly speaking, scientific divisions. It is, however, a matter of convenience to retain them in a separate form, as it is by no means absolutely certain how they may most naturally be distributed amongst the higher orders.

SUB-CLASS I. AMETABOLA. — *Young not passing through a metamorphosis, and differing from the adult chiefly in size. Imago destitute of wings; eyes simple, sometimes wanting.*

ORDER I. ANOPLURA.—*Minute Aptera, in which the mouth is formed for suction, and there are two simple eyes.*

This order comprises insects which are commonly parasitic upon man and other animals, and are known as Lice (*Pedi-*

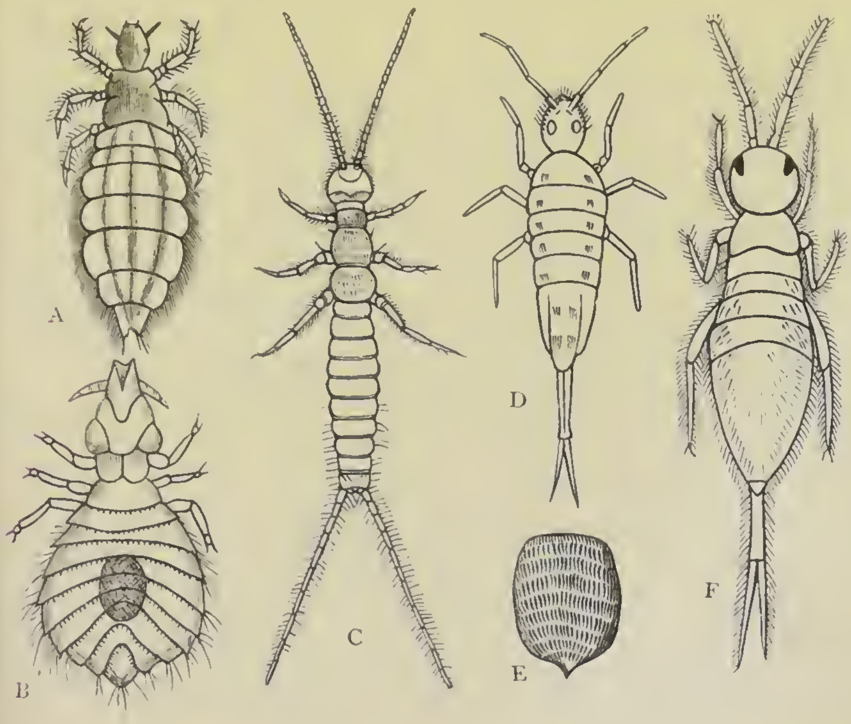

Fig. 231.—Morphology of Aptera. A, *Pediculus capitis*; B, *Docophorus hamatus*, one of the Bird-lice; C, *Campodea*; D, *Degeeria*, one of the *Poduridæ*; E, Scale of a Podurid, as seen under the microscope; F, *Degeeria purpurascens*. All the figures are greatly enlarged. (After Packard and Gervais.)

culidæ). The common Louse (fig. 231, A) is furnished with a simple eye, or ocellus, on each side of a distinctly differentiated head, the under surface of which bears a suctorial

mouth. There is little distinction between the thorax and abdomen, but the segments of the former carry three pairs of legs. The legs are short, with short claws or with two opposing hooks, affording a very firm hold. The body is flattened and nearly transparent, distinctly segmented, and showing the stigmata very plainly. The young pass through no metamorphosis, and their multiplication is extremely rapid. Many Mammals are infested by Lice, the same animal often being subject to the attacks of more than one species of Louse. Three species commonly attack man—viz., *Pediculus capitis*, *P. vestimenti*, and *Phthirius pubis*; and a fourth species (*Pediculus tabescentium*) is of rare occurrence, and gives rise to the loathsome disease known as Phthiriasis.

The Lice are now very commonly associated with the *Hemiptera*, of which they are regarded as constituting a degraded and aberrant group.

ORDER II. MALLOPHAGA.—*Minute Aptera, in which the mouth is formed for biting, and is furnished with mandibles and maxillæ.*

The members of this order (fig. 231, B) are commonly known as "Bird-lice," being parasitic, sometimes upon Mammals, but mostly upon Birds. They strongly resemble the *Pediculi*, but the mouth is formed for biting, to suit their mode of life—since they do not live upon the juices of their hosts, but upon the more delicate tegumentary appendages. Of the forms which infest Mammals, one of the most familiar is the Louse of the Dog (*Trichodectes latus*). They are sometimes regarded as constituting a degraded group of the *Hemiptera*.

ORDER III. COLLEMBOLA.—*Minute Aptera, with a semi-masticatory or suctorial mouth; the first abdominal segment furnished with a ventral tube or suctorial organ; the last abdominal segment but one with appendages for leaping.*

This order has been established by Sir John Lubbock for the reception of a number of Insects generally known as "Spring-tails." Their scientific name is in allusion to the fact that they attach themselves to foreign bodies by a double ventral suctorial tube, which secretes a viscous fluid; whilst their popular name refers to their possessing saltatory appendages attached to the last abdominal segment but one. These appendages (fig. 231, D and F) consist of a long forked process which is generally bent along the under surface of the body. When released, the sudden extension of the elastic process throws the insect into the air. The body is covered either with hairs or scales, and the latter exhibit under the microscope very elaborate and beautiful markings (fig. 231, E).

They are generally to be found in moist dark places in gardens, or on the surface of pools, and the commonest genera are *Podura*, *Smynthurus*, and *Degeeria*.

ORDER IV. THYSANURA.—*Minute Aptera, with a masticatory mouth; the end of the abdomen furnished with long bristle-like terminal appendages, used in locomotion.*

The insects of this order are closely related to those of the preceding, but the long anal bristles do not usually form a "spring"; and the mouth is distinctly masticatory. In the genus *Machilis* a "spring" is present, resembling that of the *Poduræ*. The two principal genera are *Lepisma* and *Campodea* (fig. 231, C), both of which live generally under stones or in dark situations. The body is hairy, or clothed with metallic scales; these latter organs being in *Lepisma* so delicately marked that they are commonly used as test-objects for the microscope.

According to Packard, the *Thysanura* and *Collembola* are to be regarded as degraded groups of *Neuroptera*, the former having also affinities with the *Myriopoda*. According to Sir John Lubbock, *Campodea* may be regarded as a modern representative of a group of ancient type-forms, from which the higher Insects originally took their rise.

SUB-CLASS II. HEMIMETABOLA.—*Metamorphosis incomplete; the larva differing from the imago chiefly in the absence of wings, and in size; pupa usually active, or, if quiescent, capable of movement.**

ORDER V. RHYNCHOTA (*Hemiptera*).—*Mouth suctorial, beak-shaped, consisting of a jointed rostrum, composed of the elongated labium and labial palpi, which together form a jointed, tubular sheath for the bristle-shaped, styliform mandibles and maxillæ. Eyes compound, usually with ocelli as well. Two pairs of wings in most; sometimes wanting. Pupa generally active.*

The *Hemiptera* live upon the juices of plants or animals, which they are enabled to obtain by means of the suctorial rostrum.

The order is divided into the following three sub-orders:—

Sub-order a. Homoptera.—The anterior pair of wings of the same texture throughout (membranous); the mouth

* The males of the *Coccidæ*, amongst the *Rhynchota*, undergo a complete metamorphosis. In certain of the *Rhynchota* and *Orthoptera* the adult is apterous, and in these cases there cannot be said to be any metamorphosis, since the larvæ differ from the adult only in size, in having fewer joints to the antennæ, and in having a smaller number of facets in each of the compound eyes. The typical *Neuroptera*, on the other hand, pass through a complete metamorphosis.

turned backwards, so that the beak springs from the back of the head. The wings fold over one another when the insect is at rest. There are ocelli between the

Fig. 232.—Rhynchota. Bean Aphis (*Aphis fabæ*), winged male and wingless female

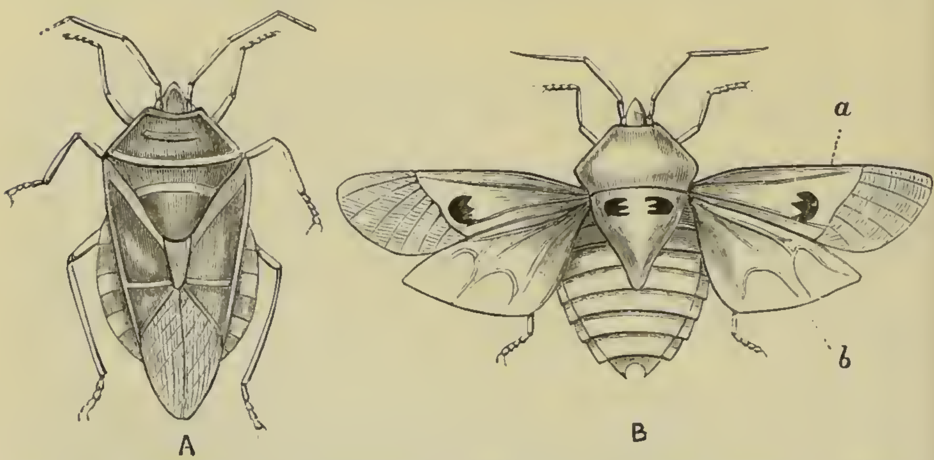

Fig. 233.—Rhynchota. A, *Pentatoma rutilans*, with the wings closed. B, *Rhaphigaster incarnatus*, with the wings expanded in flight: *a*, Anterior wing (hemelytron), with its basal portion hardened by chitine; *b*, Posterior membranous wing.

compound eyes, and the antennæ are small and composed of few joints. The females often have an ovipositor of three toothed blades. In this section are the Aphides, the Scale Insects (*Coccidæ*), the Cicadas, the Lantern-flies (*Fulgora*), &c.

As typical examples of the *Homoptera* may be taken the *Cicadas* (fig. 234, C), the males of which are well known for their power of emitting a musical note or chirp. The Plant-lice or *Aphides* (fig. 232) live upon the juices of plants, an enormous number of species being known. They may possess two pairs of membranous wings, or none, and they give birth to innumerable young in the summer months by a process of parthenogenesis. The hinder end of the abdomen usually carries two tubular organs or "cornicles" (fig. 232), from

which a sweet fluid ("honey-dew") is excreted. The singular Scale-insects (*Coccidæ*) have the males winged, whilst the females are deformed, often scale-like, and devoid of wings. The dried female of the Cochineal Insect (*Coccus cacti*) constitutes the cochineal of commerce, and the *Coccus lacca* yields lac-dye, while shell-lac is the resinous exudation which flows from the punctures which the insect makes in trees.

Sub-order b. Heteroptera.—Anterior wings membranous near their apices, but chitinous towards the base (hemelytra); the rostrum springing from the front of the head. The inner margins of the wings are straight or contiguous. The antennæ are moderate in size, and usually composed of a few large joints.

Of the external characters of the Heteropterous *Rhynchota* or "Bugs," the most marked is the peculiar nature of the anterior wings. These, namely, are in the form of "hemelytra" (fig. 233, *a*), having their bases chitinous, and their apices membranous. It was from this character that the name of *Hemiptera* has been so often given to the entire order of the *Rhynchota;* the name being, however, inappropriate, as the anterior wings are membranous in the insects belonging to the preceding section of the order.

The *Heteroptera* are divided into the two tribes of the *Hydrocorisæ* (Water-bugs), and *Geocorisæ* (Land-bugs), according as they are aquatic or mainly terrestrial in their habits. Of the former, familiar examples are the Boat-flies (*Notonecta*), and the Water-scorpions (*Nepa*, fig. 234, B). Of the latter

Fig. 234.—Rhynchota. A, *Thrips*, enlarged; B, *Nepa cinerea*, enlarged; C, *Cicada Anglica*, the wings on the right side of the body being omitted; D, Larva of the same; E, Pupa of the same. (Figs. C, D, and E are after Westwood.)

group, the most typical examples are the Forest-bugs and Field-bugs, such as *Pentatoma* (fig. 233, A). Another familiar type is the Bed-bug (*Cimex lectularius*), in which the hind-wings are absent, and the hemelytra are rudimentary.

Sub-order c. Thysanoptera. — Mouth with mandibles and maxillæ, furnished with palpi. The wings with few or no nervures, fringed. In this sub-order are only the little insects which form the genus *Thrips* (fig. 234, A), and some allied forms. They live upon plants, and differ from the typical *Rhynchota* both in the structure of the wings, and in the fact that the beak-like rostrum really contains palpate mandibles and maxillæ. The insects forming this little group are often included in the *Orthoptera*, with which they are in various respects allied.

ORDER VI. ORTHOPTERA. — *Mouth masticatory; wings four, sometimes wanting; the anterior pair mostly smaller than the posterior, semi-coriaceous or leathery*, usually with numerous nervures, the interspaces between which are filled with many transverse reticulations; sometimes overlapping horizontally (Cockroach), sometimes meeting like the roof of a house (Grasshoppers). *Posterior wings usually having their front portion of a different texture from their hinder portion*, this latter being almost always more transparent, and *when not in use folded longitudinally like a fan.* Posterior wings often wanting in the females of the *Blattidæ.* Antennæ usually filiform.

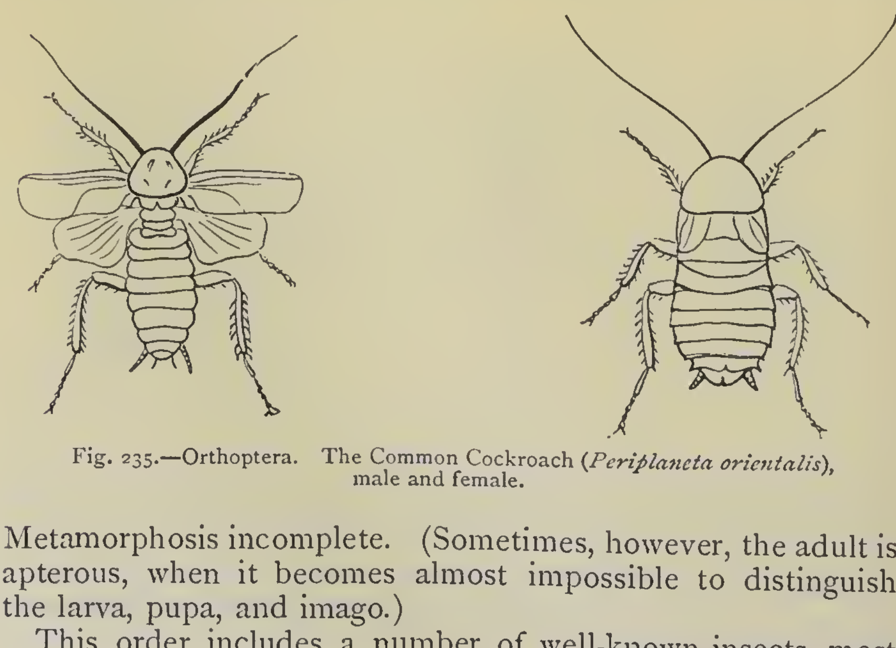

Fig. 235.—Orthoptera. The Common Cockroach (*Periplaneta orientalis*), male and female.

Metamorphosis incomplete. (Sometimes, however, the adult is apterous, when it becomes almost impossible to distinguish the larva, pupa, and imago.)

This order includes a number of well-known insects, most

of which are vegetable-feeders. Some of the *Orthoptera*, such as the Cockroaches (*Blattidæ*, fig. 235) have slender legs, and are adapted for running (*cursorial*). Others are suited for walking, and are said to be *gressorial*. Amongst these are the *Mantides*, with their great raptorial front-legs, and the singular Walking Leaves and Stick-insects (the *Phasmidæ*). Others, again, are *saltatorial*, having the hind-legs elongated and adapted for leaping (fig. 229). In this section are the Crickets and Mole-crickets (*Gryllidæ* or *Achetidæ*), and the Grass-hoppers and Locusts (*Acridiidæ* and *Locustidæ*). The Saltatory *Orthoptera* are all vegetable-feeders, and whilst many of them commit serious depredations upon green crops and grass, the ravages of the Migratory Locust (*Œdipoda migratoria*) are in this respect unrivalled. Finally, there is a small section of the *Orthoptera* which includes the Earwigs (*Forficulidæ*), and which has been raised to the rank of a distinct order under the name of *Euplexoptera*. In this group (fig. 236), the last

Fig. 236.—The Earwig (*Forficula auricularia*). A, Larva; B, Pupa; C, Imago

segment of the abdomen carries a pair of nippers, the anterior wings are very short, and the posterior wings are membranous, and are folded up both longitudinally and transversely, being useless for flight.

ORDER VII. NEUROPTERA (*Odonata*).—*Mouth usually masticatory; wings four in number, all membranous, generally nearly equal in size, traversed by numerous delicate nervures, which have a longitudinal and transverse direction, thus giving them a reticulated, lace-like aspect. Metamorphosis in some groups incomplete, in other groups complete. The larva active, hexapod, the pupa active or quiescent.*

The order *Neuroptera* includes a number of Insects which are so different in their characters, habits, and metamorphoses,

that they are sometimes placed in three separate and special groups. The first section includes what may be termed normal *Neuroptera*, such as the Ant-lions (*Myrmeleontidæ*), the Aphis-lions (*Hemerobiidæ*, fig. 237), the Scorpion-flies (*Panorpidæ*), and the *Sialidæ*. The second section includes the Dragon-flies (*Libellulidæ*), the May-flies (*Ephemeridæ*), the Stone-flies (*Perlidæ*), the White Ants (*Termitidæ*), and some less important families. These are often placed in the *Orthoptera*, under the common name of *Pseudo-neuroptera*. Lastly, we have a section sometimes elevated to the rank of a distinct order under the name of *Trichoptera*, for the reception of the singular Caddis-flies (*Phryganeidæ*). In this group the anterior wings are generally hairy, the mandibles are rudimentary, the larva usually resides in a case formed of small foreign bodies, and the pupa is inactive during the greater part of its life.

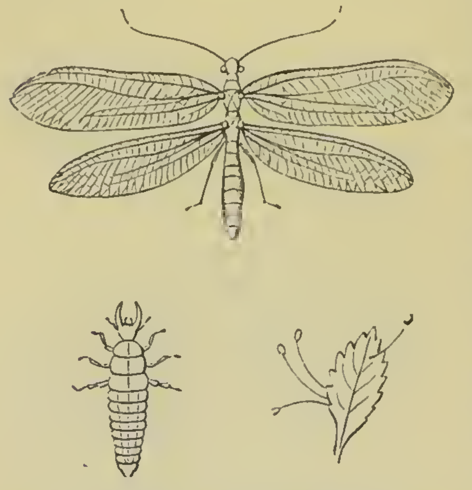

Fig. 237.—Neuroptera. Aphis-lion (*Chrysopa perla*), imago, larva, and eggs.

Amongst the more remarkable of the *Neuroptera* are the so-called "White Ants" or Termites, a brief description of which may be given here. The Termites are social insects, living in organised communities, and they are mostly inhabitants of hot countries. (It must be borne in mind that though often called "White Ants," they stand in no relation to the true Ants.) Mr Bates has given us an excellent description of the habits of these singular insects, from which much of what follows has been taken.

Each species of Termites consists of several distinct orders or castes, which live together, and constitute populous, organised communities. They inhabit structures known as "Termitaria," consisting of mounds or hillocks, some of which are "five feet high, and are formed of particles of earth worked into a material as hard as stone." The Termitarium has no external aperture for ingress or egress, as far as can be seen, the entrance being placed at some distance, and connected with the central building by means of covered ways and galleries. Each Termitarium is composed of "a vast number of chambers and irregular intercommunicating galleries, built up with particles of earth or vegetable matter, cemented together with the saliva of the insects." Many of "the very large hillocks are the work of many distinct species, each of which uses materials differently compacted, and keeps to its own portion of the tumulus."

A family of Termites (fig. 238) consists of a king and queen, of the workers, and of the soldiers. According to the researches of Lespès, Bates, and Fritz Müller, the workers and soldiers amongst the Termites are not sterile females, but *modified larvæ*, which belong to both sexes, and

are arrested in their development (or, rarely, males and females in which the reproductive organs are rudimentary). Fritz Müller has further discovered that, in addition to the winged males and females which are periodically produced in great numbers, there exists in some, if not in all,

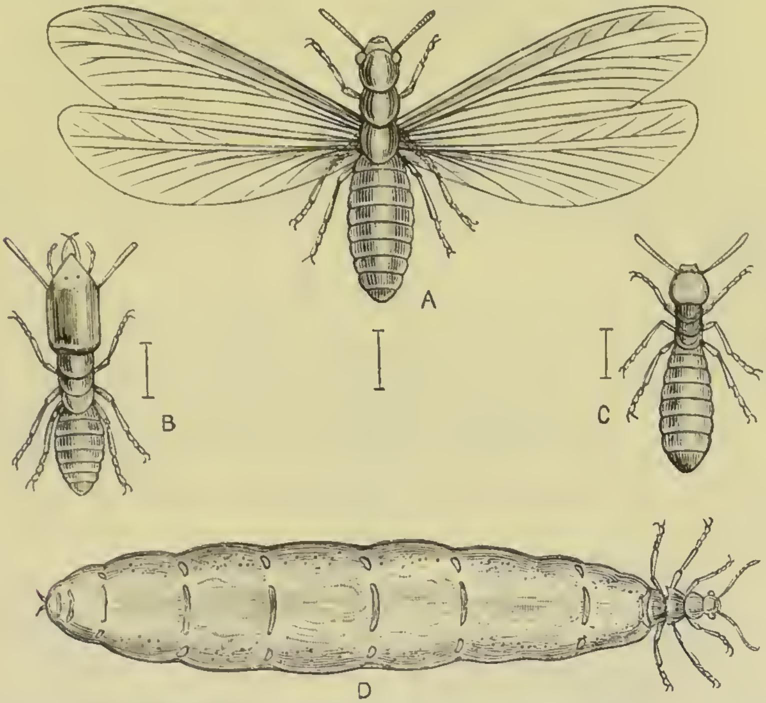

Fig. 238.—Different individuals of the colony of one of the Termites. A, The queen before the wings are shed; D, The queen after the wings are thrown off and the abdomen has become greatly distended with eggs; C, Worker; B, Soldier.

of the species a second set of males and females, which are destitute of wings. These complementary males and females never leave the termitary in which they are born; and they may take the place of the winged males and females whenever a community fails to secure a royal couple at the proper period. The royal couple are the parents of the colony, and "are always kept together, closely guarded by a detachment of workers, in a large chamber in the very heart of the hive, surrounded by much stronger walls than the other cells. They are both wingless, and immensely larger than the workers and soldiers. The queen, when in her chamber, is always found in a gravid condition, her abdomen enormously distended with eggs, which, as fast as they come forth, are conveyed, by a relay of workers, in their mouths, from the royal chamber to the minor cells dispersed through the hive."

At the beginning of the rainy season a number of *winged* males and females are produced, which, when they arrive at maturity, leave the hive and fly abroad. They then shed their wings (a special provision for this existing in a natural seam running across the root of the wing and dividing the nervures); they pair, and then become the kings and queens of future colonies.

The workers and the soldiers are distinct from the moment of their emergence from the egg, and they do not acquire their special characteris-

tics in consequence of any difference of food or treatment. Both are wingless, and they differ solely in the armature of the head. The duties of the workers are to "build, make covered roads, nurse the young brood from the egg upwards, take care of the king and queen, who are the progenitors of the whole colony, and secure the exit of the males and females when they acquire wings, and fly out to pair and disseminate the race." The duties of the soldiers are to defend the community from all attacks which may be made upon its peace, for which purpose the mandibles are greatly developed.

SUB-CLASS III. HOLOMETABOLA.—*Metamorphosis complete; the larva, pupa, and imago differing greatly from one another in external appearance. The larva vermiform, and the pupa quiescent.*

ORDER VIII. APHANIPTERA. — *Wings rudimentary, in the form of scales situated on the mesothorax and metathorax. Mouth suctorial. Metamorphosis complete.*

This order comprises the Fleas (*Pulicidæ*), which are parasitic upon various animals, both Mammals and Birds, each species, as a rule, attacking some particular host. The larva of the common Flea (*Pulex irritans*, fig. 239) is an apodal

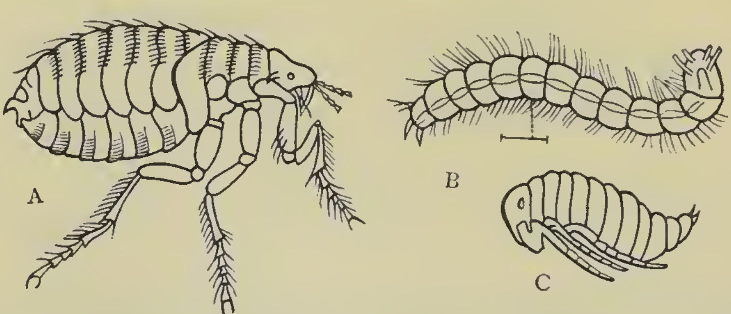

Fig. 239.—A, The Common Flea (*Pulex irritans*); B, Larva of the same; C, Pupa o the same. All the figures are greatly magnified. (After Westwood.)

grub, which in about twelve days spins a cocoon for itself, and becomes a quiescent pupa, from which the imago emerges in about a fortnight more.

The Chigoe or Sand-flea (*Sarcopsylla penetrans*) of the tropical parts of America, is a more serious pest than the common Flea. It is, however, only a parasite as regards the impregnated females; the males, unimpregnated females, and larvæ leading a free existence. The impregnated females, however, bore their way through the skin of the foot in the human subject, and live there till they assume the size of peas, by the distension of the abdomen with eggs, often occasioning great local irritation and inflammation. They also live beneath the skin of mice and dogs.

Many authorities regard the *Aphaniptera* as a degraded group of the *Diptera*.

ORDER IX. DIPTERA.—*The anterior pair of wings alone developed; the posterior pair of wings rudimentary, represented by a pair of clubbed filaments, called "halteres," or "balancers"* (fig. 240). *In a few the wings are altogether wanting. Mouth*

Fig. 240.—Diptera. Crane-fly (*Tipula oleracea*).

suctorial. The metamorphosis is complete, the larvæ being generally destitute of feet; but in some cases (e.g., *the Gnats*) *the pupæ are aquatic and are actively locomotive. In most cases, however, the pupæ are quiescent.*

The proboscis in the *Diptera* consists of a tubular labium enclosing the styliform or lancet-shaped mandibles and maxillæ, and is placed on the under surface of the head. Ocelli are present in addition to the compound eyes. The wings are generally horizontal and transparent, the nervures not very numerous, and for the most part longitudinally disposed. The anterior wings usually have appended to their hinder margin, at their base, a pair of little membranous flaps (the "alulæ"), which are to be regarded as separate and detached elements of the front wings. The antennæ are generally small and three-jointed (*Brachycera*), sometimes many-jointed (*Tipulidæ*), or feathery (*Culicidæ*). The larva is soft and fleshy, with a soft indistinct head, usually apodal,

never with thoracic legs, and rarely with pro-legs. The larval skin mostly forms a hardened case for the pupa, but the larvæ sometimes cast their skin when becoming pupæ, or even spin cocoons. When the pupa is enclosed in the hardened larval skin, none of its parts are recognisable, and it is said to be "coarctate." In other cases, the pupa has its own investment, and the limbs are enclosed in separate sheaths, and are therefore visible, when the pupa is said to be "obtected." In the Gnats, the larvæ and pupæ are aquatic (fig. 241), and the pupa

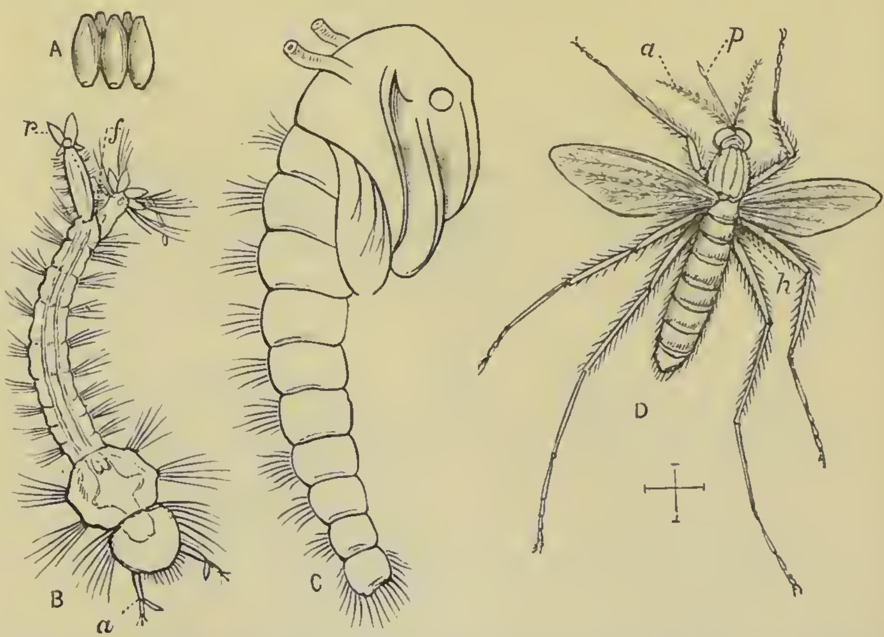

Fig. 241.—The Common Gnat (*Culex pipiens*). A, A few of the eggs, attached together to form a raft, which floats on the water; B, The larva, suspended in the water head-downwards, and showing the antennæ (*a*), the terminal respiratory tube (*r*), and the fins attached to the extremity of the body (*f*); C, The pupa, with the two respiratory tubes attached to the thorax; D, The adult insect, with the well-developed front wings, the rudimentary hind wings or "balancers" (*h*), the antennæ (*a*), and the proboscis (*p*). All the figures are greatly enlarged.

is active, though it does not feed. The larva breathes by means of a long tube attached to the penultimate segment of the abdomen, into which the tracheæ open, and which the insect thrusts above the water for the purpose of obtaining air. This abdominal tube has disappeared in the pupa (fig. 241, C), respiration being now carried on by means of two tubes appended to the dorsal aspect of the thorax, which project above water when the insect rises to the surface, and which carry air to the tracheæ.

In one section of the *Diptera*, hence termed *Pupipara*, the larvæ continue to reside within the mother until they are just

ready to become pupæ, and they are born in a form closely resembling the ordinary pupæ of the members of the order. In the Hessian Fly (*Cecidomyia*) the larva produces asexually a number of secondary larvæ, which are developed within the body of the primitive larva, and feed upon its tissues, ultimately causing its death.

The *Diptera* constitute one of the largest of the orders of the *Insecta*. Amongst the more important forms included in this division may be enumerated the House-flies, Bluebottles, and Flesh-flies (*Muscidæ*); the Gnats, Midges, and Mosquitos (*Culicidæ*); the Bot-flies (*Œstridæ*); the Gad-flies (*Tabanidæ*); the Forest-flies and Sheep-ticks (*Hippoboscidæ*); and the Crane-flies (*Tipulidæ*).

ORDER X. LEPIDOPTERA.—*Mouth* (fig. 226) *suctorial, consisting of a spiral trunk or "antlia," composed of the greatly-elongated maxillæ, and protected, when not in use, by the cushion-shaped hairy labial palpi. Maxillæ forming two sub-cylindrical half-tubes, united together by inosculating hooks, and constituting an intermediate tube by their junction. Maxillary palpi minute; labrum and mandibles rudimentary. Head, thorax, and abdomen more or less covered with hair. Wings, four in number, covered with modified hairs or scales; wanting in the females of a few species. Nervures not very numerous, mostly longitudinal. Antennæ composed of numerous minute joints.*

This well-known and most beautiful of all the orders of Insects comprises the Butterflies (fig. 242) and the Moths (fig. 243); the former being diurnal in their habits, the latter mostly crepuscular or nocturnal.

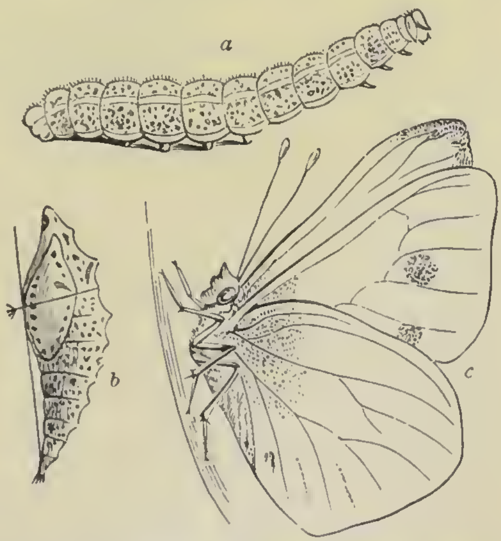

Fig. 242.—Large White Cabbage Butterfly (*Pieris brassicæ*). *a* Larva or caterpillar; *b* Pupa or chrysalis; *c* Imago or perfect insect.

The larvæ of *Lepidoptera* (fig. 242), commonly called "caterpillars," are vermiform in shape, normally composed of thirteen segments, the first of which forms a distinct horny head, with antennæ, jaws, and usually simple eyes. The mouth of the caterpillar, unlike that of the perfect insect, is formed for mastication. The

labium, also, is provided with a tubular organ—the "spinneret"—which communicates with two internal glands, the functions of which are to furnish the silk, whereby the animal constructs its ordinary abode or spins its cocoon. The viscera are embedded in a largely developed fatty tissue (epiploön), which is absorbed by the pupa during its period of quiescence. The three segments behind the head correspond with the prothorax, mesothorax, and metathorax of the perfect insect, and each carries a pair of jointed walking-legs. Besides these thoracic legs, there is a variable number (generally five pairs) of soft fleshy legs, which are borne by the segments of the abdomen, and are known as "pro-legs." Each is usually furnished with a crown of one or more rows of small horny hooks, and they are never attached to the 4th, 5th, 10th, and 11th segments behind the head (*i.e.*, to the 1st, 2d, 7th, or 8th abdominal segments). The last pair of pro-legs are often spoken of as the "claspers." The larvæ of the "Looper" Moths (*Geometridæ*) have only these and the pair of pro-legs in front of these. The larvæ moult repeatedly, eat voraciously, and increase very rapidly in size. The pupæ are of the "obtected" type, the entire body being enclosed in a horny skin, but showing the division into thorax and abdomen, and having the limbs readily discernible, though enclosed in the chitinous pellicle of the chrysalis. The form of the pupa is very variable, and the duration of the pupal stage differs much in different groups.

In the Diurnal *Lepidoptera*, or Butterflies proper (fig. 242), the antennæ are generally knobbed (hence the name of *Rhopalocera* often given to the group); the wings are usually held erect when the insect is in a state of repose; the larvæ have six thoracic legs and ten pro-legs; and the pupæ are always naked, attached by the posterior extremity, or head downwards, and usually angular. In some cases the pupa is suspended, horizontally or vertically, by a fibre of silk across its thorax.

The Moths (fig. 243) constitute the largest section of the *Lepidoptera*, and are mostly night-flying insects, though many are "crepuscular" in their habits—*i.e.*, are active in the twilight, and a good many forms are only active during the daytime, thus resembling the true Butterflies in habit. The antennæ are exceedingly variable in form, and the name of *Heterocera* is often given to the Moths on this ground. They are usually either fusiform, or they grow thicker from the base to the apex, or diminish in size from the base to the apex, and they are very commonly pectinated, or furnished with lateral processes,

while they are very rarely clubbed at their ends. The wings are held in a horizontal position, or are folded over the back, when the insect is at rest. In many cases there is a peculiar

Fig. 243.—Goat-moth (*Cossus ligniperda*) and caterpillar.

arrangement ("retinaculum") by which the hind-wings are kept in contact with the front-wings during flight. The pupæ are never angular, and are mostly smooth, and they are often enclosed in a cocoon, which the larva spins before it passes into the pupal stage. Of the larger Moths the principal families are the *Sphingidæ* (Hawk-moths), the *Bombycidæ* (Silk-moth, Emperor-moth, &c.), and the *Noctuidæ* (Night-moths). On the other hand, many of the Moths (*Tineidæ, Tortricidæ, Pyralidæ*, &c.) are of small size, and are often grouped together under the name of *Microlepidoptera*.

ORDER XI. HYMENOPTERA.—*Wings four, membranous, with few nervures; sometimes absent. Mouth always provided with biting-jaws or mandibles; the maxillæ and labium generally converted into a suctorial organ. Females having the extremity of the abdomen furnished with an ovipositor* (*terebra or aculeus*), *consisting generally of five or six pieces, of which the two outer form a protective sheath.* Besides the compound eyes, there are

usually three ocelli placed on the top of the head. The antennæ are generally filiform or setaceous. The metamorphosis is complete, but the various parts of the pupa are visible through the delicate enclosing membrane. The larvæ are sometimes provided with feet, and live on vegetable food (as in the *Tenthredinidæ*, fig. 245); but they are mostly footless, without a distinct head, and fed by the adult.

The *Hymenoptera* form a very extensive order, comprising the Bees, Wasps, Ants, Ichneumons, Saw-flies, &c. The ovipositor, which is characteristic of the females of this order, is very commonly modified so as to constitute a saw (*serra*), a boring organ (*terebra*), or a sting (*aculeus*).

As regards the principal groups of the *Hymenoptera*, the Saw-flies (*Tenthredinidæ* and *Siricidæ*) form a very natural sec-

Fig. 244.—*a* Winged male of Ant ; *b* Wingless worker of Ant ; *c* Pupa of Ant ; *d* Larva of Ant, enlarged ; *e* The Great Saw-fly (*Sirex gigas*).

tion, which is often spoken of as that of the *Terebrantia*, as the females have the ovipositor converted into a saw or borer. The larvæ of the Saw-flies (fig. 245) feed upon vegetable matter, and have pro-legs. Another important group is that of the Gall-flies (*Cynipidæ*), all of which lay their eggs in the soft tissues of plants (generally the leaves). The resulting "galls" are due to the abnormal cell-growth excited locally in the plant by the irritation caused by the puncture of the mother's ovipositor in depositing the eggs. The larvæ are footless. In the allied group of the Ichneumons (*Ichneumonidæ*), the larvæ are also footless, and the eggs are deposited by the females in the larvæ or pupæ of other insects, upon whose

tissues the young support themselves after hatching. All the other *Hymenoptera* have the ovipositor of the female connected with a poison-gland, and converted into a sting (not always the case in the Ants), and they may therefore be grouped together under the common title of *Aculeata*. The principal families included under this name are the Ants (*Formicidæ*), the Wasps (*Vespidæ*), the Hornets (*Crabronidæ*), the Bees (*Apidæ*), and the Bumble-bees (*Bombidæ*).

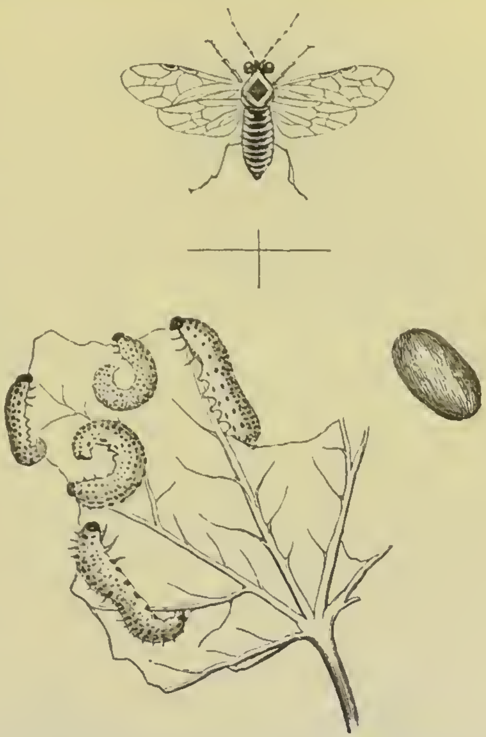

Fig. 245.—Gooseberry Saw-fly (*Tenthredo grossulariæ*), larva, pupa, and imago.

Amongst the *Hymenoptera* we find social communities, in many respects resembling those of the Termites, of which a description has already been given. The societies of Bees and Ants are well known, and merit a short description.

The social Bees, of which the common Honey-bee (*Apis mellifica*) is so familiar an example, form organised communities, consisting of three classes of individuals—the males, females, and neuters. As a rule, each community consists of a single female—"the queen"—and of the neuters, or "workers." The impregnation of the female is effected by the production of males, or "drones," during the summer. After impregnation has been effected, the drones, as being then useless, are destroyed by the workers. The eggs produced by the fecundated queen are mostly intended to give origin to neuters, to which end they are placed in the ordinary cells. The ova which are to give origin to females—the "queens" of future colonies—are placed in cells of a peculiar construction, and the larvæ are fed by the workers with a special food. The ova which are to produce males are likewise placed in cells which are slightly larger than those allotted to the workers. This, however, is not the sole or true cause of the production of the males; but the ova which are intended to produce drones are not fertilised by the female with the semen which she has stored up in her spermatheca, and are therefore produced by a process of parthenogenesis.

In the Bumble-bees (*Bombidæ*), and in the Wasps (*Vespidæ*), we have societies essentially the same as in the Honey-bee. In a large community of Wasps, or "vespiary," there may be several hundred females, of which few survive the winter, and live to found fresh colonies next spring. The number of males is about equal to that of the females, but, unlike the drones of the Bees, the males work actively

and defend the nest. As amongst the Bees, solitary species are not uncommon.

The Ants (*Formicidæ*) likewise form communities, consisting of males, females, and neuters (fig. 244). The males and females, as we have seen in the case of the Termites, are winged, and are produced in great numbers at a particular period of the year. They then quit the nest and pair, after which the males die. The females then lose their wings and fall to the ground, when they become the queens of fresh societies. In some Ants, as in the Termites, the neuters are divided into two classes—the workers and the soldiers—of which the former perform all the duties necessary for the preservation of the society except defending the nest, this being left to the soldiers. In other cases, as many as three distinct orders or "castes" of neuters may be present in the same nest.

Amongst the more singular of the habits and instincts of Ants two may be mentioned—the instinct of making slaves, and that of milking, so to speak, the little Plant-lice (*Aphides*). As regards the first of these, it is found that certain Ants possess the extraordinary instinct of capturing the pupæ of other species of Ants, and bringing them up as slaves. The relations between the masters and the slaves vary a good deal in different species. In the case of *Polyergus rufescens*, for instance, the masters are entirely dependent upon their slaves; the males and females do nothing except reproducing the species, and the neuters perform no other labour except that of capturing fresh slaves. The masters are in this case unable even to feed themselves, and their existence is maintained entirely by the devotion of the slaves. In *Formica sanguinea*, on the other hand, the number of slaves is much less, and both masters and slaves occupy themselves in performing most of the duties necessary for the community. The masters, however, go alone when on slave-making expeditions; and in case of a migration, the masters carry the slaves in their mouths.

A second singular fact in the history of Ants is found in the relations which subsist between them and the *Aphides*, or Plant-lice. The *Aphides* secrete, or rather excrete, a peculiar viscid and sweet liquid, by means of two tubular filaments ("cornicula") which open externally towards the hinder extremity of the abdomen. Ants are extremely fond of this excretion, and it is a well-established fact that the *Aphides* allow themselves to be *milked*, as it were, by the Ants. For this purpose the Ant touches and caresses the abdomen of the Aphis with its antennæ, whereupon the latter voluntarily exudes a drop of the coveted fluid.

The belief that our European Ants stored up grain for winter consumption, though generally asserted by the ancients, has been, until recently, discredited by scientific observers, upon the ground that our Ants are known to be carnivorous in their habits. Mr Moggridge has, however, recently shown that there are exceptions to this rule, and that some of the Ants of the south of Europe (such as some of the species of *Atta*) not only eat vegetable food, but really execute the feats imputed to them by the old writers. They do, namely, store up a provision of grain for the winter, and they prevent this from germinating by gnawing the radicle.

ORDER XII. STREPSIPTERA.—*Females without wings or feet, parasitic. Males possessing the posterior pair of wings, which are large, membranous, and folded longitudinally like a fan. The anterior pair of wings rudimentary, represented by a pair of singular twisted organs. Jaws rudimentary.*

The *Strepsiptera* constitute a small order, which includes

certain parasites of minute size, found on Bees and other *Hymenoptera*. The female is a soft vermiform grub, without feet or wings, but with a horny head, which it protrudes from between the abdominal segments of its host. The larvæ are active, and possess six feet; whilst the males (fig. 246) are winged, and fly about with great activity.

Fig. 246.—Strepsiptera. *Stylops Spencii*, greatly magnified (after Westwood).

The *Strepsiptera* are now very generally regarded as an anomalous and degraded group of the *Coleoptera*.

ORDER XIII. COLEOPTERA. —*Mouth masticatory, furnished with an upper lip or labrum, two mandibles, two maxillæ with maxillary palpi* (*generally four-jointed*), *and a movable lower lip or labium, with two jointed labial palpi. The four wings are usually present, and the anterior pair are not adapted for flight,*

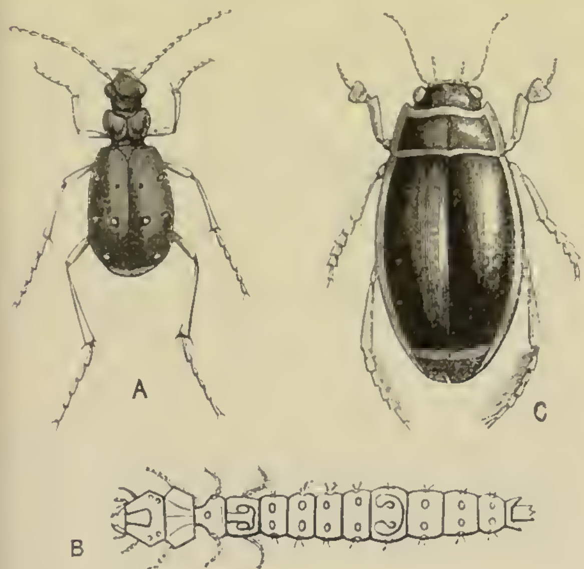

Fig. 247.—Coleoptera. A, *Cicindela campestris*, the Tiger-beetle, enlarged. B, Larva of the same, enlarged. C, *Dytiscus marginalis*, male.

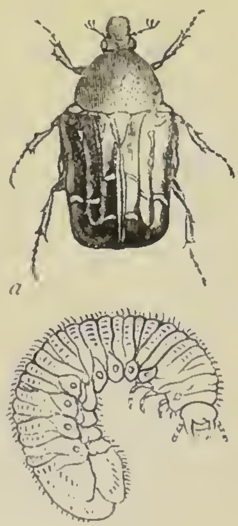

Fig. 248.—*a* Rose-chafer (*Cetonia aurata*) and larva.

but are hardened by chitine, so as to form protective cases (*elytra*) *for the posterior wings* (fig. 247). *The inner margins of the elytra are generally straight, and when in contact they form a*

longitudinal suture. The posterior wings are membranous, and when not in use are folded transversely beneath the elytra. (Amongst deviations from this state of parts may be mentioned the occasional absence or rudimentary condition of the hinder wings, the soldering together of the elytra, the soft and yielding condition of the elytra, or the absence of both elytra and wings.) The eyes are always compound, generally circular, oval, or reniform, but sometimes completely divided. The antennæ are extremely variable in form, generally of eleven joints, sometimes of fewer, rarely of twelve or more. The thorax is composed of a pro- meso- and meta-thorax, but when the elytra are closed, only the prothorax and a little plate ("scutellum") belonging to the mesothorax are visible. The tarsus is generally composed of five joints, sometimes fewer, never more, and its last joint is usually furnished with two hooked claws.

The larvæ of *Coleoptera* (figs. 247, 248) are generally composed of thirteen segments, including the head. The body is generally soft and fleshy, the head horny, and the mouth adapted for mastication, the food being sometimes of an animal and sometimes of a vegetable nature. The antennæ are small, usually of three or four joints, with ocelli at their bases. They have three pairs of legs attached to the thorax, and rarely anal pro-legs or fleshy tubercles; or they may be devoid of feet (as in the Weevils). The pupa is sometimes enclosed in a cocoon, and is always quiescent; and the parts of the perfect insect are always distinctly recognisable in the pupa.

The order *Coleoptera* includes all those insects commonly known as "Beetles," and comprises an enormous number of genera and species. They are remarkable, as a general rule, for their hard polished integument, their glittering, often metallic colours, and their voracious habits.

The order *Coleoptera* was divided by Latreille into four sections, in accordance with the number of the joints in the tarsi; and though the resulting arrangement is not strictly natural, this classification is generally followed. The four sections founded by Latreille are :—

1. TRIMERA.—Tarsus three-jointed. *Ex.* Lady-birds (*Coccinellidæ*).
2. TETRAMERA.—Tarsus four-jointed. *Ex.* The Longicorn Beetles (*Longicornia*), the Weevils (*Rhynchophora*), &c.
3. HETEROMERA.—Tarsus of the two anterior pairs of legs five-jointed, of the posterior pair four-jointed. *Ex.* The Blister-beetles (*Cantharidæ*), and the great family of the *Tenebrionidæ*.
4. PENTAMERA.—Tarsus five-jointed in all the legs. *Ex.* Soldier-beetles (*Telephorus*), Glow-worm (*Lampyris*), the *Elateridæ* (the larvæ known as "Wire-worms"), the beautiful *Buprestidæ*, the

great group of the Lamellicorn Beetles (such as the Stag-beetle. Cockchafer, Dung-beetle, &c.), the Burying Beetles (*Necrophorus*). the Devil's-coach-horses (*Staphylinidæ*), the Water-beetles (*Hydrophilidæ* and *Dytiscidæ*), the Whirligigs (*Gyrinidæ*), the Ground-beetles (*Carabidæ*), and the Tiger-beetles (*Cicindelidæ*).

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MOLLUSCOIDEA.

CHAPTER XXXVI.

POLYZOA.

We may consider here, under the name of *Molluscoidea*, the two groups of animals which are known respectively as the *Polyzoa* and the *Brachiopoda*. These two groups, in many respects closely allied to one another, present affinities on the one hand to the Worms, and on the other hand to the *Mollusca*, with both of which they have been arranged by different systematists. In the present state of our knowledge, however, it seems best to consider these two groups separately, without referring them definitely to either of the two sub-kingdoms above-mentioned. The Tunicates, which have also often been included amongst the Molluscoids, may likewise be in the meanwhile regarded as a separate division, which finds its most natural position between the *Mollusca* and the *Vertebrata*.

The *Molluscoidea* may be briefly defined as unsegmented, simple or compound animals, with bilateral symmetry. The mouth is furnished with a crown of ciliated tentacles, or with spirally-rolled ciliated processes. The nervous system consists of a single ganglion, or of an œsophageal nerve-ring with more than one ganglion. A heart is absent or present. Under this head may be placed the two classes of the *Polyzoa* and the *Brachiopoda*.

Polyzoa.

Class I. Polyzoa (*Bryozoa*).—The members of this class are mostly *composite animals, each zoöid of which possesses, typically, a freely suspended alimentary canal with mouth and anus, enclosed within a double-walled sac. The mouth is sur-*

rounded with a circle or crescent of hollow ciliated tentacles, and the nervous system consists of a single ganglion placed between the mouth and the anus.

With the single exception of the genus *Loxosoma*, all the *Polyzoa* live in an associated form in colonies or "polyzoaria," which are sometimes foliaceous (fig. 249), sometimes branched

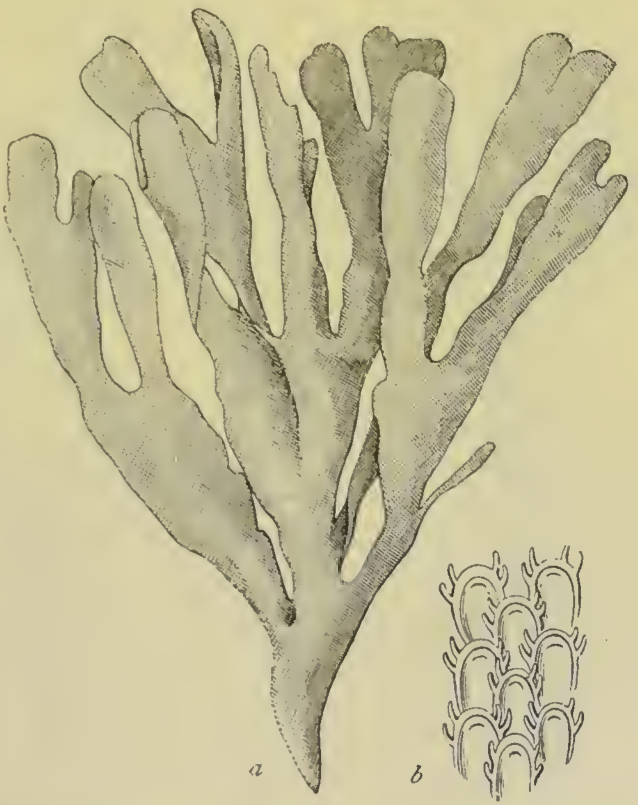

Fig. 249.—*Flustra foliacea*, one of the Sea-mats. *a* Portion of the colony, natural size; *b* A fragment magnified, to show the cells in which the separate polypides are contained.

and plant-like, sometimes encrusting, and very rarely are free. Each "polyzoarium" consists of an assemblage of distinct but similar zoöids arising by continuous gemmation from a single primordial individual. The colonies thus produced are in very many respects closely similar to those of many of the Hydroid Polypes, with which, indeed, the *Polyzoa* were for a long time classed.

In the *Polyzoa*, the entire colony—or its entire dermal system—is called the "polyzoarium" or "cœnœcium"; the separate zoöids are called "polypides"; and the little chambers in which each is contained are called the "cells," or "zoœcia."

The structure of a typical polypide of a *Polyzoön* is thus described by Professor Allman (figs. 250 and 251):—

"Let us imagine an alimentary canal, consisting of œsophagus, stomach, and intestine, to be furnished at its origin

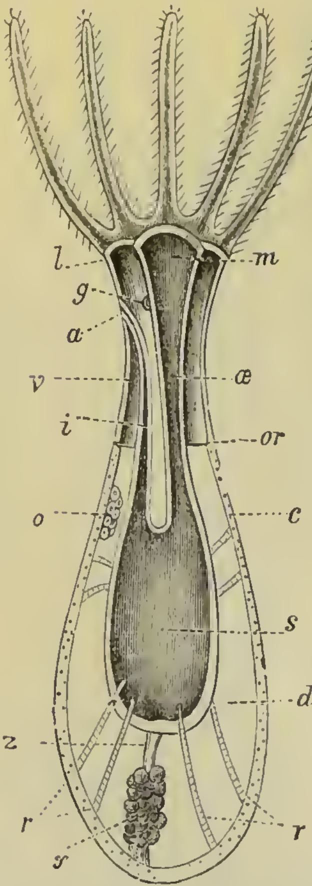

Fig. 250.—Diagram showing the structure of a single polypide of a Polyzoan (after Busk). *l* Tentacles; *m* Mouth; *g* Nerve-ganglion; *œ* Gullet; *s* Stomach; *i* Intestine; *a* Anus; *o* Ovary; *x* Testis; *z* Funiculus; *or* Aperture of the zoœcium; *v* Tentacular sheath; *d* Perivisceral cavity; *r* Retractor muscles.

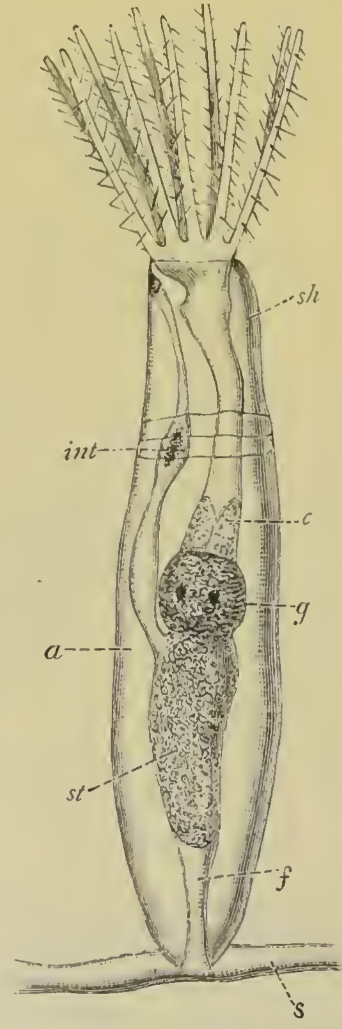

Fig. 251.—A single polypide of *Bowerbankia*, greatly enlarged. (After Hincks.) *sh* Tentacular sheath; *a* Cell-wall; *s* Common stem or stolon, from which the polypides are budded off; *c* Cardiac valve of gullet; *g* Gizzard; *st* The stomach proper; *int* Intestine; *f* Funiculus.

with long ciliated tentacula, and to have a single nervous ganglion placed upon one side of the œsophagus. Let us now suppose this canal to be bent back upon itself towards the side of the ganglion, so as to approximate the termination to

the origin. Let us further imagine the digestive tube thus constituted to be suspended in a fluid contained in a membranous sac with two openings, one for the mouth and the other for the vent, the tentacula alone being external to the sac. Let us still further suppose the alimentary tube, by means of a system of muscles, to admit of being retracted or protruded according to the will of the animal; the retraction being accompanied by an invagination of the sac, so as partially or entirely to include the oral tentacles within it; and if to these characters we add the presence of true sexual organs in the form of ovary and testis, occupying some portion of the interior of the sac, and the negative character of the absence of all vestige of a heart, we shall have, perhaps, as correct an idea—apart from all considerations of homology or derivation from an archetype—as can be conveyed of the essential structure of a *Polyzoön* in its simplest and most generalised condition.

"To give, however, more actuality to our ideal *Polyzoön*, we may bear in mind that the immediately investing sac has the power, in almost every case, of secreting from its external surface a secondary investment, of very various constitution in the different groups; and we may, moreover, conceive of the entire animal with its digestive tube, tentacula, ganglion, muscles, generative organs, circumambient fluid, and investing sac, repeating itself by gemmation, and thus producing one or more precisely similar systems holding a definite position relatively to one another, while all continue organically united, and we shall then have the actual condition presented by the *Polyzoa* in their fully-developed state."

The vast majority of the *Polyzoa* are fixed, but this is not universally the case. Thus the singular fresh-water *Cristatella* is free and locomotive, creeping about by means of a flattened discoid base, not unlike the foot of the *Gastropoda;* and the polyzoary seems to have been unattached in a few other forms (*Selenaria*, *Cupularia*, &c.)

The two fundamental structures of the "polypide" of a *Polyzoön*—viz., the immediately investing sac, and its secondary investment—are sometimes termed the "endoderm" and "ectoderm"; but as these terms are employed in describing the *Hydrozoa*, it is better to make use of the terms "endocyst" and "ectocyst," proposed by Dr Allman.

The "ectocyst," or external investment of the cœnœcium, is usually a brown, pergamentaceous, probably chitinous, but often highly calcareous, membrane; and it is by the ectocyst that the "cells" are formed. In *Cristatella*, alone of the

Polyzoa, there is no ectocyst; and in *Lophopus* (fig. 253, 3) and in the curious *Pectinatella* the ectocyst is gelatinous in its consistence.

The "cells" or "zoœcia" of the *Polyzoa* vary extremely in form and structure in different groups. In the so-called "Cyclostomatous" *Polyzoa* the cells are tubular, and end in round terminally-placed mouths, which have no special apparatus for their closure. On the other hand, in the so-called "Cheilostomatous" *Polyzoa*, the cell-apertures are usually placed on the front face of the cells towards one end, and they have their orifices closed by a movable opercular valve. Though the separate zoœcia of a Polyzoan colony are usually apparently quite separate and distinct from one another, except by continuity of their external investment, it has been shown that contiguous cells are commonly placed in direct connection with one another by what have been called by Hincks "communication-plates." These are portions of the cell-wall pierced by one or more minute pores which transmit processes of the structure which will be subsequently described as the "endosarc."

In many cases the ectocyst is provided with singular appendages, supposed to be weapons of defence, or organs of prehension, termed "avicularia" and "vibracula." The avicularia, or "bird's-head processes" (fig. 252, B and C), differ a good deal in shape, but consist essentially of "a movable mandible and a cup furnished with a horny beak, with which the point of the mandible is capable of being brought into apposition" (Busk). In shape the avicularia often closely resemble the head of a bird, and they are in many respects comparable with the "pedicellariæ" of the *Echinodermata*, keeping up a constant snapping movement which continues long after the death of the general colony. In the "vibracula" (fig. 252, A), the place of the mandible of the avicularium is taken by a bristle, or seta, which is capable of extensive movement.

In many of the marine *Polyzoa*, the cells are likewise furnished with globular sacs or pouches appended to one end, and serving as marsupial pouches for the ova (fig. 252, A). These brood-pouches (known as the "ovicells" or "oœcia") are periodically produced, and the eggs are conveyed into them from the perivisceral cavity of the parent-cell. Ultimately the ciliated embryos are liberated from the ovicell, and escape into the surrounding water.

There is every reason to regard the vibracula, avicularia, and ovicells as not being mere appendages of the cœnœcium,

but rather as being specially modified zoöids. Good authorities also believe that the "cells" or "zooœcia" themselves are not to be regarded as mere skeletal structures, but that they

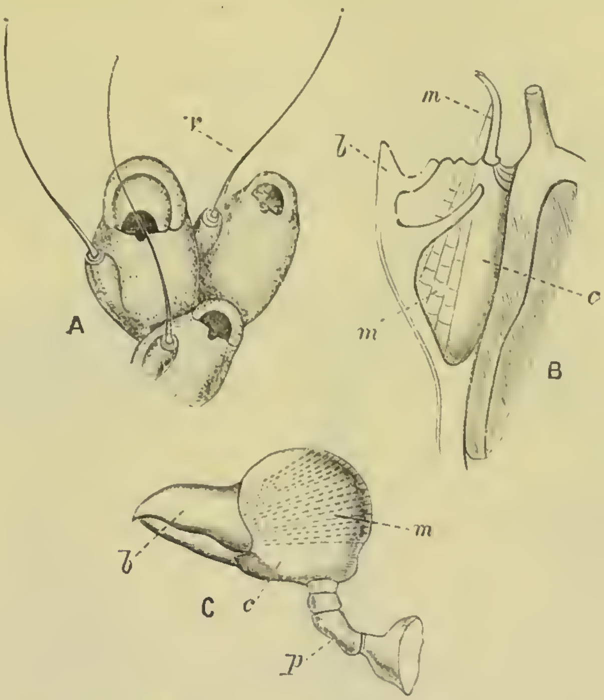

Fig. 252.—A, Three cells of *Mastigophora Hyndmanni*, showing vibracula (*v*). The left-hand cell also shows an oœcium. B, Sessile avicularium of *Scrupocellaria scruposa;* and C, Pedunculate avicularium. *a* Mandible; *b* Beak; *c* Chamber of the avicularium; *m* Muscles; *p* Peduncle. All the figures are enlarged. (After Hincks and Busk.)

have a life independent of that of their contained polypides, and that they can continue to live and produce new polypides after the death of the latter. They are regarded, in fact, as separate zoöids. This view is supported by the fact that the life of the cell is quite independent of that of the contained polypide. It is, indeed, a common phenomenon for the polypide to degenerate and die, and to be replaced by a new polypide budded out from the zoœcium.

The endocyst is always soft, contractile, and membranous; and, according to Sars, is wanting in *Rhabdopleura*. It lines the interior of the cells formed by the ectocyst, and is reflected backwards at the mouth of the cell, so as to be invaginated, or inverted into itself (forming the so-called "tentacular sheath"); and it finally terminates by being attached to the base of the circlet of tentacles. This invagination of the endocyst is more or less permanently present in all the fresh-

water *Polyzoa.* The epithelium lining the inner surface of the endocyst is furnished with vibratile cilia.

The mouth of each polypide is surrounded by a crown of tubular, non-retractile tentacles, which have their sides ciliated, and are arranged sometimes in a circle and sometimes in a crescent. In the fresh-water *Polyzoa* the tentacles are united towards their bases by a funnel-shaped membrane, known as the "calyx." The tentacles are borne on a kind of disc, or stage, which is termed by Professor Allman the "lophophore."

In the majority of *Polyzoa*—including almost all the marine species—the lophophore is circular (fig. 253, 2); but in most

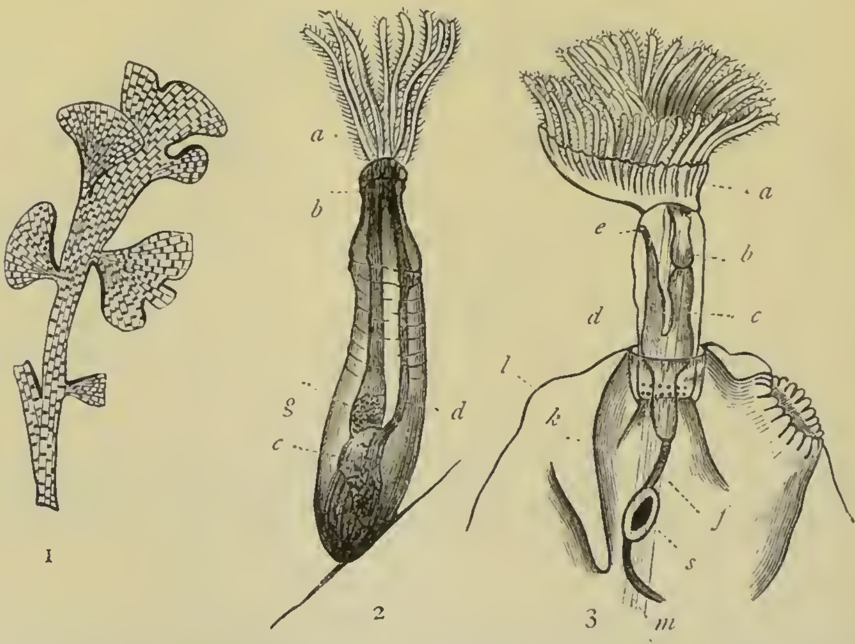

Fig. 253.—1. Fragment of *Flustra truncata*, one of the Sea-mats, natural size. 2. A single polypide of *Valkeria*, magnified, showing the orbicular crown of tentacles. 3. A polypide of *Lophopus crystallinus*, a fresh-water Polyzoön, highly magnified, showing the horse-shoe-shaped crown of tentacles. *a* Tentacular crown; *b* Gullet; *c* Stomach; *d* Intestine; *e* Anus; *g* Gizzard; *k* Endocyst; *l* Ectocyst; *f* Funiculus.

of the fresh-water forms it has its neural side extended into two long arms, so that the entire lophophore becomes crescentic or "horse-shoe-shaped" (fig. 253, 3); hence this section is sometimes collectively termed the "Hippocrepian" *Polyzoa.* In all, or almost all, the *Polyzoa* in which this crescentic condition of the lophophore exists, there is also a singular valve-like organ which, springing from the anal side of the lophophore, arches over the mouth, and is termed the "epistome." It has been compared with the "foot" of the *Mollusca.* The only marine forms in which the lophophore is bilateral are

Pedicellina and *Rhabdopleura*; the only fresh-water species in which the lophophore is orbicular are *Paludicella* and *Urnatella*.

The mouth conducts by an œsophagus into a dilated stomach. In some cases a pharynx may be present, and in others there is in front of the stomach a muscular proventriculus, or gizzard. From the stomach proceeds the intestine, which shortly turns forward to open by a distinct anus close to the mouth. As the nervous ganglion is situated on that side of the mouth towards which the intestine turns in order to reach its termination, the intestine is said to have a "neural flexure"; and this relation is constant throughout the entire class.

Respiration in the *Polyzoa* appears to be carried on by the ciliated tentacles, and by the "perigastric space," which is filled with a clear fluid, containing solid particles in suspension. A kind of circulation is kept up in this "perigastric fluid" by means of the cilia lining the inner surface of the endocyst. Beyond this there is nothing that could be called a circulation, and there are no distinct circulatory organs of any kind.

The nervous system in all the *Polyzoa* consists of a single small ganglion (fig. 250, *g*), placed upon one side of the œsophagus, between it and the anal aperture, and apparently really of a double nature.

The so-called "colonial nervous system" of the *Polyzoa* is now generally regarded as not being of a nervous nature, and it is usually spoken of as the "endosarc." This singular system commences as a peculiar cellular cord, the "funiculus" (figs. 250 and 251), which stretches from the base of the stomach to the bottom of the zoœcium, and upon which the testis is developed. At the point where the funiculus is fixed to the bottom of the cell, a perforation in the ectocyst exists, and filaments of the funiculus thus either pass into adjacent polypides, or become connected with a common branched fibre which runs through the stolons of the colony (as in *Bowerbankia*, fig. 251). In many cases the endosarcal cords give off branching fibres, and they have a general likeness to a nervous system. Histologically, however, the endosarc does not consist of nervous elements, and it may be regarded as a kind of cœnosarcal structure, which is largely connected with the production of the generative elements, and from which, possibly, the polypides are produced by gemmation.

The muscular system is well developed, and consists of various muscular bands, with special functions attaching to

each. The most important fasciculi are the retractor muscles (fig. 250, *r*), which retract the upper portion of the polypide within the cell. These muscles arise from the inner surface of the endocyst near the bottom of the cell, and are inserted into the upper part of the œsophagus. The polypide, when retracted, is again exserted, chiefly by the action of the "parietal muscles," which are in the form of circular bundles running transversely round the cell.

The great majority of the *Polyzoa* are hermaphrodite, each polypide containing an ovary and testis (fig. 250). The ovary may be situated near the summit of the cell, attached to the inner surface of the endocyst; or it may spring from the "funiculus." The testis is always situated towards the bottom of the cell, and is attached to the "funiculus." There are no proper efferent ducts to the reproductive organs, and the generative elements are set free into the perigastric space. In some cases the spermatozoa are expelled from the polypide which produced them (in some cases by organs corresponding with "segmental organs"); but in other cases the ova appear to be fecundated within the body-cavity of the parent polypide. The fertilised ova may pass into oœcia (when these structures are present), or the embryos may be hatched within the perivisceral cavity of the parent. The precise mode in which the larvæ in these cases ultimately gain the exterior, differs in those instances in which it has been investigated, and in many types is not known at all.

As already mentioned, continuous gemmation occurs in all the *Polyzoa* (with the exception of *Loxosoma*), the fresh zoöids thus produced remaining attached to the organism from which they were budded forth, and thus giving rise to a compound growth.

A form of discontinuous gemmation, however, occurs in many of the Polyzoa, in which certain singular bodies, called "statoblasts," are developed in the interior of the polypide. The statoblasts are found in certain seasons lying loose in the perigastric cavity. In form "they may be generally described as lenticular bodies, varying, according to the species, from an orbicular to an elongated-oval figure, and enclosed in a horny shell, which consists of two concavo-convex discs united by their margins, where they are further strengthened by a ring which runs round the entire margin, and is of different structure from the discs. . . . When the statoblasts are placed under circumstances favouring their development, they open by the separation from one another of the two faces, and there then escapes from them a young *Polyzoön*, already in an advanced stage of development, and in all essential respects resembling the adult individual in whose cell the statoblasts were produced" (Allman). The statoblasts are formed as buds upon the "funiculus"—the cord already alluded to as extending from the testis to the stomach—upon which they may usually be

seen in different stages of growth. They do not appear to be set free from the perigastric space prior to the death of the adult, and when liberated they are enabled to float near the surface of the water, in consequence of the cells of the marginal ring, or "annulus," being spongy and filled with air. They must be looked upon as "*gemmæ* peculiarly encysted, and destined to remain for a period in a quiescent or pupa-like state" (Allman).

As regards the development of the *Polyzoa*, the embryo upon its emergence from the ovum presents itself as a ciliated, free-swimming, sac-like body, from which the polypide is subsequently produced by a process of gemmation.

According to the classification proposed by Nitsche, and now generally adopted, the *Polyzoa* are divided into the two primary sections of the *Entoprocta* and the *Ectoprocta*, to which a third must be added, under the name of *Aspidophora*, for the reception of the anomalous *Rhabdopleura*. The following are the principal groups of the *Polyzoa* :—

A. Ectoprocta.

Mouth within the circle of tentacles; anus dorsal and outside the tentacular circle; lophophore crescentic or circular.

Sub-order I. *Phylactolæmata.*
,, ,, II. *Gymnolæmata.*

The Phylactolæmatous *Polyzoa* are inhabitants of fresh water, and the lophophore is bilateral and horse-shoe-shaped in all except *Fredericella*. They also possess the peculiar valve-like organ, arching over the mouth, which is known as the "epistome," and which possibly corresponds with the Molluscan "foot." The division of the *Gymnolæmata*, on the other hand, includes the fresh-water genera *Paludicella* and *Urnatella* and the vast majority of the marine *Polyzoa*. In this section the lophophore is circular, and there is no epistome. Of the marine *Polyzoa*, the sub-order of the *Cheilostomata* is the most important, as embracing the greater number of the common forms. In these, the opening of the cell is sub-terminal, and is generally closed by a movable lip or shutter. On the other hand, in the sub-order *Cyclostomata*, the cells are tubular, the orifices terminal, of the same diameter as the cell itself, and without any movable apparatus for closure. Lastly, in the singular group of the *Ctenostomata* (including *Vesicularia*, *Alcyonidium*, and *Valkeria*), the cells arise from a common tube, and their mouths are terminal, and furnished with a setose fringe for their closure.

B. Entoprocta.

Mouth and anus both within the circle of tentacles; lophophore horse-shoe-shaped. Tentacles solid and non-retractile, filled, like the body-cavity, with parenchyma. Ectocyst not calcified. This division includes the marine *Pedicellina* and *Loxosoma*, and the fresh-water *Urnatella*. *Loxosoma* is semiparasitic, and is attached to the bodies of Gephyreans and other marine animals.

C. Aspidophora.

This division includes only the singular marine genus *Rhabdopleura*, in which the lophophore is crescentic, and carries a discontinuous series of

tentacles; the mouth is lateral rather than terminal; a special shield-like organ is attached to the body of the lophophore, between the mouth and the anus; the cœnœcium is chitinous and tubular, and is supported by a correspondingly divided chitinous rod, attached superiorly to a fleshy contractile cord, which is in turn connected with the body of the polypites; and, lastly, the endocyst and tentacular sheath are wanting.

As regards their *distribution in space*, the *Polyzoa*, like all the *Molluscoidea*, are exclusively aquatic in their habits, but unlike the *Brachiopoda*, they are not exclusively confined to the sea. The marine *Polyzoa* are of almost universal occurrence in all seas. The fresh-water *Polyzoa*, however, not only differ materially from their marine brethren in structure, but appear to have a much more limited range, being, as far as is yet known, principally characteristic of the north temperate zone. Britain can claim the great majority of the described species of fresh-water *Polyzoa*, but this is probably due to the more careful scrutiny to which this country has been subjected. Fresh-water *Polyzoa* have also been found in the southern hemisphere, in Australia and India.

As regards their *distribution in time*, the *Polyzoa* have left abundant traces of their past existence in the stratified rocks, commencing in the Ordovician formation, and extending up to the present day. The only groups which are known with certainty to be represented in the fossil condition are those of the *Cyclostomata* and *Cheilostomata*. The Palæozoic types, such as the Lace-corals and their allies (*Fenestella*, *Ptilopora*, *Ptilodictya*, &c.), belong to peculiar groups of the class, and with one or two doubtful exceptions, are all referable to the *Cyclostomata*. In the Secondary rocks, Cyclostomatous *Polyzoa* are exceedingly abundant, but the *Cheilostomata* do not appear, in any numbers at any rate, until the horizon of the Chalk is reached, after which time they show a gradually increasing development till the Recent period is reached.

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CHAPTER XXXVII.

BRACHIOPODA.

CLASS II. BRACHIOPODA (*Palliobranchiata*).—The members of this class are defined by the possession of a *body protected by a bivalve shell, which is lined by an expansion of the integument, or "mantle." The mouth is furnished with two long spirally-coiled cirriferous processes or "arms," which act as respiratory organs. The nervous system consists of an œsophageal ring, upon which infra-œsophageal and supra-œsophageal ganglia are developed. One or two pairs of tubular "nephridia" are present, which act as ducts to the reproductive organs. The sexes are distinct or united.*

The *Brachiopoda* are essentially very similar in structure to the *Polyzoa*, from which they are distinguished by the fact that they are never composite, and by the possession of a bivalve,

calcareous, or sub-calcareous shell. They are commonly known as "Lamp-shells," and are all inhabitants of the sea. All the living forms, except *Lingula pyramidata*, are fixed to some solid object in their adult condition; but there is good reason to believe that many of the fossil forms were unattached and free in their fully grown condition. From the presence of a bivalve shell, the Brachiopods have often been placed near the true Bivalve Molluscs (the *Lamellibranchiata*), but their organisation is of a very different type.

The two valves of the shell of any *Brachiopod* (figs. 254,

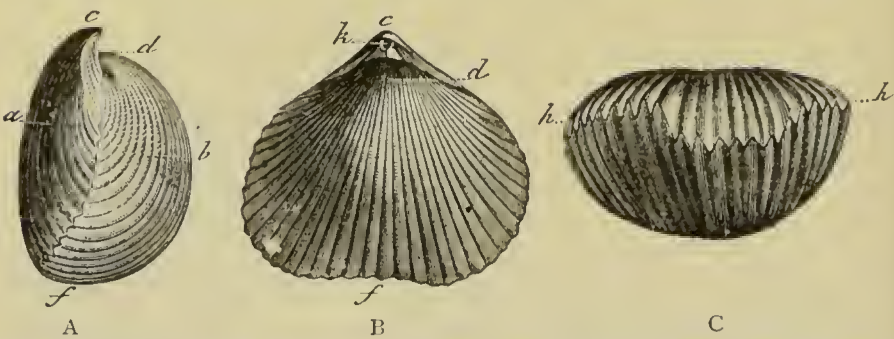

Fig. 254.—*Rhynchonella sulcata*. A, Profile view; B, View of the dorsal surface; C, View of the base. *a* Ventral valve; *b* Dorsal valve; *f* Base; *c* Beak; *h* Foramen. Lower Cretaceous.

255) are articulated together by an apparatus of teeth and sockets, or are kept in apposition by muscular action alone. One of the valves is always slightly, sometimes greatly, larger than the other, so that the shell is said to be "inequivalve." As regards the contained animal, the position of the valves is anterior and posterior, so that they are therefore termed respectively the "ventral" and "dorsal" valves. In the ordinary Bivalve *Mollusca* (*Lamellibranchiata*), on the other hand, the two valves of the shell are usually of the same size (equivalve), and they are situated upon the sides of the animal; so that, instead of being dorsal and ventral, they are now termed "right" and "left" valves. The ventral valve in the shell of the *Brachiopoda* is usually the largest, and usually possesses a prominent curved beak. The beak (figs. 254, 255) is often perforated by a "foramen," or terminal aperture, through which there is transmitted a muscular peduncle, whereby the shell is attached to some foreign object. In some cases, however (as in *Lingula*, fig. 258, B), the peduncle simply passes between the apices of the valves, and there is no foramen; whilst in others (as in *Crania*, fig. 258, D) the shell is merely attached by the substance of the

ventral valve. The dorsal or smaller valve is always free, and is never perforated by a foramen.

In intimate structure, the shell of most of the *Brachiopoda* consists "of flattened prisms, of considerable length, arranged parallel to one another with great regularity, and at a very acute angle—usually only about 10°

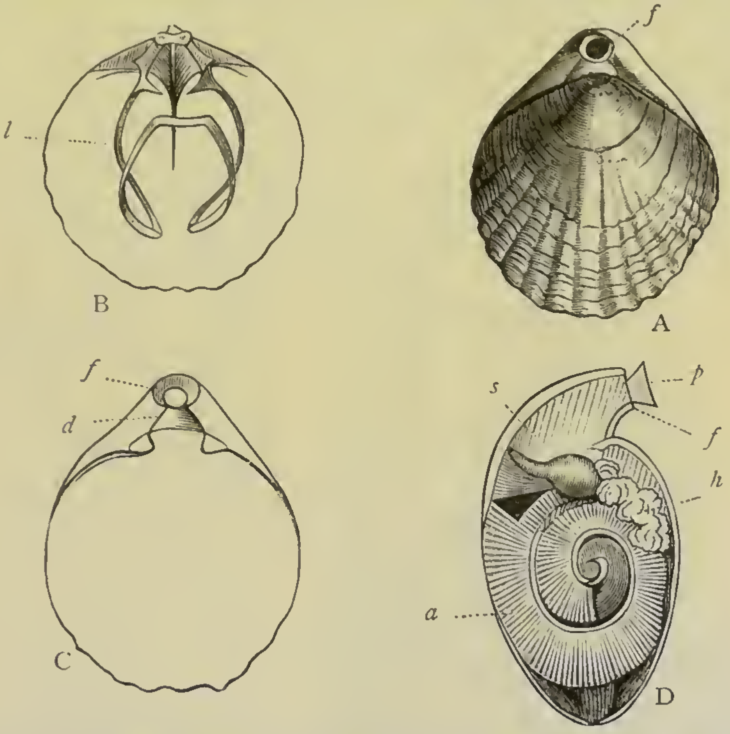

Fig. 255.—*Terebratula* (*Waldheimia*) *flavescens*. A, The shell viewed from behind, showing the dorsal valve, and the perforated summit of the ventral valve above it. B, Inner view of the dorsal valve, showing the shelly loop (*l*) which supports the spiral arms. C, Inner view of the ventral valve, showing the foramen or aperture (*f*) in the beak, through which the muscular stalk of attachment passes. D, Longitudinal and vertical section of the animal, showing the spiral arms (*a*), the stomach (*s*), and the liver (*h*). At *f* is the opening in the beak, with the stalk of attachment (*p*) passing through it. (After Davidson and Owen.) Some details have been omitted in Figs. B, C, and D, for the sake of clearness.

or 12°—with the surfaces of the shell" (Carpenter). In most cases, also, the shell is perforated by a series of minute canals, which pass from one surface of the shell to the other, in a more or less vertical direction, usually widening as they approach the external surface. These canals give the shells a "punctated" structure, and in the living animal they contain cæcal tubuli, or prolongations, from the mantle, which are considered by Huxley as analogous to the vascular processes by which in many Ascidians the muscular tunic, or "mantle," is attached to the outer tunic, or "test." In some of the *Brachiopoda* (as in the *Rhynchonellidæ*) the shell is "impunctate," or is devoid of this singular canal-system.

Though characteristically calcareous, the shell of the *Brachiopoda* may sometimes be largely composed of horny matter (as in *Discina*); or the carbonate of lime in the horny shell may be almost wholly replaced by phosphate (as in *Lingula*).

The inner surface of the valves of the shell is lined by expansions of the integument which secrete the shell, and which constitute the "lobes" of the "pallium," or "mantle." The digestive organs and muscles occupy a small space near the beak of the shell, which is partitioned off by a membranous septum, which is perforated by the aperture of the mouth. The remainder of the cavity of the shell is almost filled by two long oral processes, which are termed the "arms," and from which the name of the class has been derived (fig. 256, *h*). These organs are lateral tubular prolongations of the margins of the mouth, usually of great length, closely coiled up, and fringed on one side with ciliated lateral processes, or "cirri." In many Brachiopods the arms are supported upon a more or less complicated internal calcareous framework or skeleton (fig. 255, B), which is sometimes called the "carriage-spring apparatus," and which in many extinct forms is coiled into a shelly spiral.

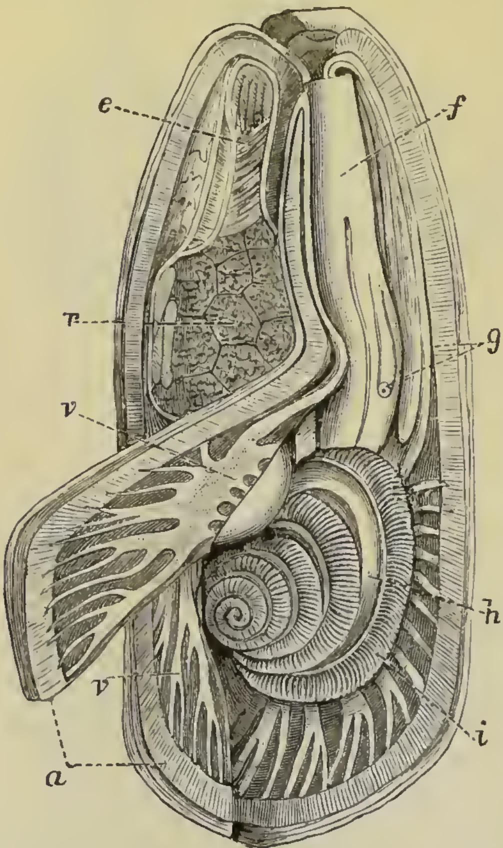

Fig. 256.—Anatomy of *Lingula anatina*. Enlarged. (After Hancock.) *a* The two lobes of the mantle, the dorsal lobe being partly turned back; *v v* Sinuses in the lobes of the mantle; *h* Spirally-coiled "arms," bearing lateral cirri (*i*); *g* Anus; *r* Liver.

The mouth conducts by an œsophagus into a distinct stomach, surrounded by a well-developed granular liver. The intestine is sometimes short, at other times long and coiled, and it may either terminate in a distinct anal aperture (as in *Lingula*, fig. 256, *g*), or it terminates blindly in the middle line (as in *Terebratula*). A distinct heart is often present, situated on the dorsal side of the stomach, and giving off blood-vessels; but the circulation is carried on principally through the lacunæ and interstices between the tissues. The function of respiration seems to be mainly performed by the cirriferous oral arms,

as it is by the homologous tentacular crown of the *Polyzoa.* The canal-system of the mantle, which will be spoken of immediately, is also probably partly concerned in respiration.

The two lobes of the mantle are channelled out into a system of branched tubes, which end in cæcal extremities, and into which the generative organs project. These so-called "atrial" canals communicate with the pallial cavity by means of two or four organs which correspond with the "segmental organs" of the Annelides or the "nephridia" of the Molluscs, and which have been commonly described under the names of "pseudo-hearts" or "oviducts." Each nephridial tube consists of two saccular divisions, of which the inner is connected with the "atrial canals" of the pallial lobe, while the outer opens into

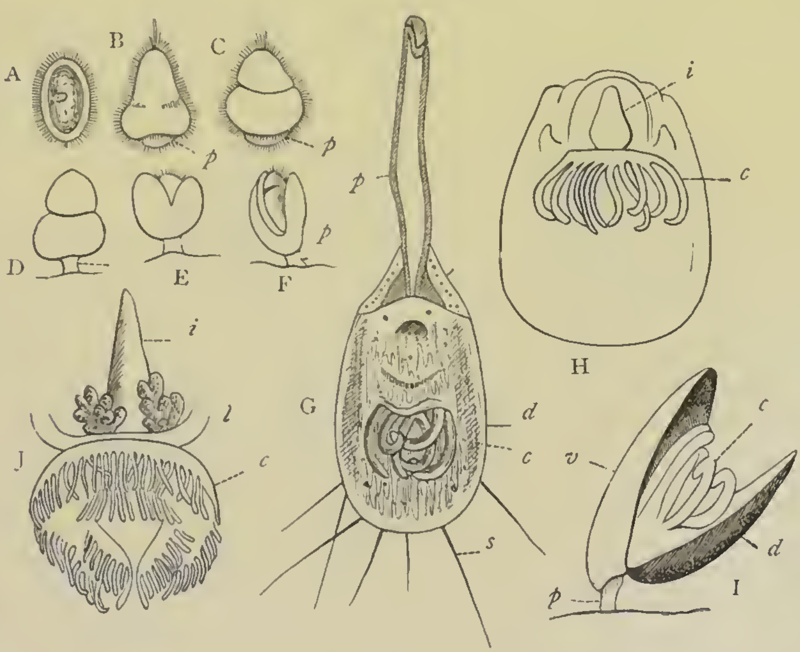

Fig. 257.—Development of *Terebratulina septentrionalis* (after Morse). A, Ciliated embryo. B, More advanced embryo, showing commencing segmentation and a rudimentary peduncle (*p*). C, D, E, F, Further stages of the same embryo. G, Advanced embryo, with a very long peduncle (*p*), and a circular oral crown of cirri (*c*). H, Interior of dorsal valve, showing the circular crown of cirri, and the intestine (*i*). I, Another larva, at the same stage, having the valves opened, and viewed from one side. J, part of a larva still further advanced, showing the now horse-shoe-shaped crown of cirri. *p* Peduncle; *v* Ventral valve of shell; *d* Dorsal valve; *c* Crown of oral cirri; *i* Intestine; *s* Setæ springing from the edge of the mantle; *l* Loop of dorsal valve. (All the figures are highly magnified.)

the mantle-cavity. The nephridial tubes act as efferent ducts to the reproductive organs, and are probably at the same time to be regarded as of the nature of kidneys or excreting organs.

The nervous system consists of an œsophageal ring, which

bears a large subœsophageal ganglion, and two small supra-œsophageal ganglia. No organs of sense have been certainly detected.

The sexes in the *Brachiopoda* appear to be ordinarily distinct, but in some forms they are asserted to be united in the same individual. As regards the process of development in the class, we may take as a type *Terebratulina septentrionalis*, the metamorphoses of which have been most ably worked out by Professor Morse. In this form, the earliest embryo is a ciliated planula (fig. 257, A), which swims about actively, and soon (B) exhibits a division into three regions or segments, which rapidly become more conspicuous (C). Of these segments, the most inferior (*p*) becomes the future peduncle, and serves to attach the embryo to some foreign body (D). The middle segment then enlarges, and partially encloses the anterior segment (E and F), the latter ultimately being withdrawn entirely within the former, which becomes converted into the shell-secreting pallial lobes. Next the arms begin to bud out from the sides of the mouth (G), forming at first a circular crown of cirri (*c*), which forcibly calls to mind the orbicular lophophore of the Gymnolæmatous *Polyzoa*. The peduncle, at first long (as in *Lingula*), becomes rapidly shorter (I), and the oral crown of tentacles becomes distinctly horse-shoe-shaped (J), thus strikingly resembling the similarly-shaped lophophore of the "Hippocrepian" *Polyzoa*. The cirrated "arms" of the adult are finally produced by the growth and development of the free end of the horse-shoe.

AFFINITIES OF THE BRACHIOPODA.—Great differences of opinion exist at the present day as to the affinities and precise systematic position of the *Brachiopoda;* but it is impossible to do more here than merely point out these differences. The relationship of the *Brachiopods* to the *Polyzoa* is admitted on all hands to be very close; and we may regard the encrusting members of the latter class as being "communities of Brachiopods, the valves of which are continuous and soldered together, the flat valve forming the united floor, whilst the convex valve does not cover the ventral valve, but leaves an opening more or less ornamented for the extension of the lophophore" (A. Agassiz). Until recently, most naturalists have held that both these groups had strongly-marked relationships with the *Lamellibranchiata*, and many still adhere to this view. On the other hand, the view has been gaining ground, that these groups are to be regarded as comprising modified Worms, and they are often placed in the immediate neighbourhood of the *Annelida*. The chief grounds for this view are to be found in the similarity of the development of the Polyzoans and Brachiopods to that of the Annelides, as shown by the elaborate researches of Morse and Kowalewsky. Apart from embryological likeness, one of the most striking links between the Brachiopods and the Annelides is the aberrant *Lingula pyramidata*—the genus *Lingula* being itself an aberrant type. This curious form (fig. 258, A), as described by Morse, differs from its congeners in not being fixed, but in living free in the sand. Its peduncle is long and worm-like, hollow, and highly contractile, and its lower end is encased in a sand-tube, resembling that of a Tubicolous Annelide. Whilst it must be freely admitted that the affinities between the *Brachiopoda* and the *Annelides* are much closer than any outward resemblance between the two would lead us to expect, a sufficient case for the removal of the former to the "*Vermes*" has hardly been made out.

DIVISIONS OF THE BRACHIOPODA.—The *Brachiopoda* may be divided into the two orders of the *Inarticulata* (or *Tretenterata*) and the *Articulata* (or *Clistenterata*).

In the first of these orders (*Inarticulata*), the valves of the shell are not united along the hinge-line, the mantle-lobes are completely free, and the intestine terminates in a distinct anus. In this division are included the three families of the *Craniadæ*, *Discinidæ*, and *Lingulidæ*—all very ancient,

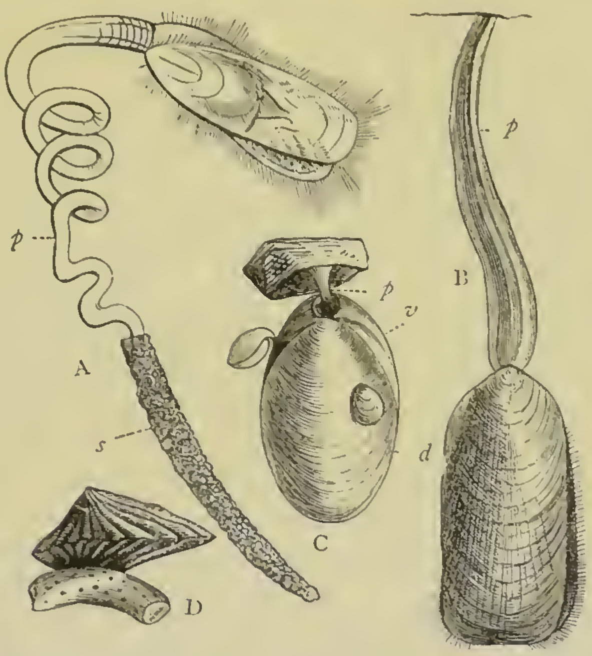

Fig. 258.—Morphology of *Brachiopoda*. A, *Lingula pyramidata* (after Morse): *p* Peduncle; *s* Sand-tube. encasing base of peduncle. B, *Lingula anatina* (after Cuvier); *p* The peduncle. C, *Waldheimia cranium*, with adherent young, attached to a stone (after Davidson): *p* Peduncle; *v* Ventral valve; *d* Dorsal valve. D, *Crania Ignabergensis*, attached by its ventral valve to a piece of coral (Chalk).

and all represented at the present day by living forms—together with the Palæozoic family of the *Trimerellidæ*.

In the second order (*Articulata*), the valves of the shell are united by teeth along the hinge-line, the lobes of the mantle are not completely free, and the intestine ends blindly. In this division are included the living families of the *Terebratulidæ*, *Rhynchonellidæ*, and the *Thecidiidæ*, and the extinct families of the *Spiriferidæ*, *Pentameridæ*, *Strophomenidæ*, and *Productidæ*. In the first two of these families the arms are supported upon a shelly loop, of variable shape and size (fig. 255, B); whilst in some of the extinct *Rhynchonellidæ* and in the *Spiriferidæ*, the arms were supported by large spirally-coiled calcareous lamellæ.

Distribution of Brachiopoda in Space.—All the known Brachiopods live in the sea, and though very local in their distribution, they may be said to have a very wide range. Though sometimes found between tide-marks, and more commonly in comparatively shallow water, they are essentially deep-water forms, living most generally in depths of from 100 to 500 fathoms. A few forms have been found at depths of

from 2000 to over 2500 fathoms. Rather more than 100 species of living Brachiopods are known.

DISTRIBUTION OF BRACHIOPODA IN TIME.—The *Brachiopoda* are found from the Cambrian rocks up to the present day, and present us with an example of a group which appears to be slowly dying out. Nearly four thousand extinct species have been described, and the class appears to have attained its maximum in the Ordovicio-Silurian epoch, which is, for this reason, sometimes called the "Age of Brachiopods." Numerous genera and species are found also in both the Devonian and Carboniferous formations. In the Secondary rocks *Brachiopoda* are still abundant, though less so than in the Palæozoic period. In the Tertiary epoch a still further diminution takes place, and at the present day we are acquainted with few more than a hundred living forms. Of the families of *Brachiopoda*, the *Productidæ*, *Strophomenidæ*, and *Spiriferidæ* are the more important extinct types. Of the genera, the most persistent is the genus *Lingula*, which commences in the Cambrian rocks, and has maintained its place up to the present day, though it appears to be gradually dying out.

According to Woodward :—"The hingeless genera attained their maximum in the Palæozoic age, and only three now survive (*Lingula*, *Discina*, *Crania*)—the representatives of as many distinct families. Of the genera with articulated valves, those provided with spiral arms appeared first, and attained their maximum while the *Terebratulidæ* were still few in number. The subdivision with calcareous spires disappeared with the Liassic period, whereas the genus *Rhynchonella* still exists. Lastly, the typical group, *Terebratulidæ*, attained its maximum in the Chalk period, and is scarcely yet on the decline."

Of the families of the *Brachiopoda*, the *Productidæ* and *Strophomenidæ* are exclusively Palæozoic. The *Spiriferidæ* are mainly Palæozoic, but extend into the Lias, where they finally disappear. The *Lingulidæ* commence in the Cambrian period, and have survived to the present day. The *Rhynchonellidæ*, *Craniadæ*, and *Discinidæ* commence in the Ordovician period, and are represented by living forms in existing seas. The *Thecidiidæ* extend from the Trias to the present day ; and the *Terebratulidæ* appear to commence in the Silurian, and are well represented by living forms.

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MOLLUSCA.

CHAPTER XXXVIII.

SUB-KINGDOM MOLLUSCA.

The *Mollusca* may be defined as soft-bodied, bilaterally symmetrical, not definitely segmented animals. The anterior part of the body is very generally developed into a distinct head, bearing one or more pairs of soft tactile processes or tentacles. The mouth is anterior, the alimentary canal is completely shut off from the general cavity of the body, and the anus is primitively posterior. The nervous system consists of a small number of paired ganglia. A distinct vascular system and a systemic heart are present. One or more pairs of kidneys (sometimes a single kidney) are present as saccular organs ("nephridia"), which open internally into the body-cavity, and communicate with the exterior by a pore placed near the anus. Commonly there is an external or internal "shell."

The body of a Mollusc exhibits a distinct dorsal and ventral surface, and a right and left side. The dorsal surface is covered by a fold of the integument which constitutes what is called the "mantle" or "pallium," and which may be greatly expanded laterally, or may form a complete sac enclosing all the viscera. The so-called "mantle-cavity" or "pallial chamber" is the space included between the lateral prolongations of the mantle and the sides of the body.

From the ventral side of the body there is, typically, developed an unpaired median muscular mass, which constitutes what is called the "foot." The foot (fig. 259, *f*) may show a distinct division into an anterior, a middle, and a posterior region, and it is often furnished with distinct lateral pro-

longations ("epipodia"). The foot undergoes remarkable modifications in different groups of the *Mollusca*.

The alimentary canal commences at the mouth (fig. 259, *m*), which may or may not be provided with an apparatus of teeth, or furnished with tactile processes. The digestive tube is commonly of considerable length, and usually shows a gullet, into which salivary glands pour their secretion, a stomach, and an intestine. The rectum terminates at the anal aperture (fig. 259, *a*), which is primitively at the hinder end of the body, but which in many forms ultimately becomes shifted further

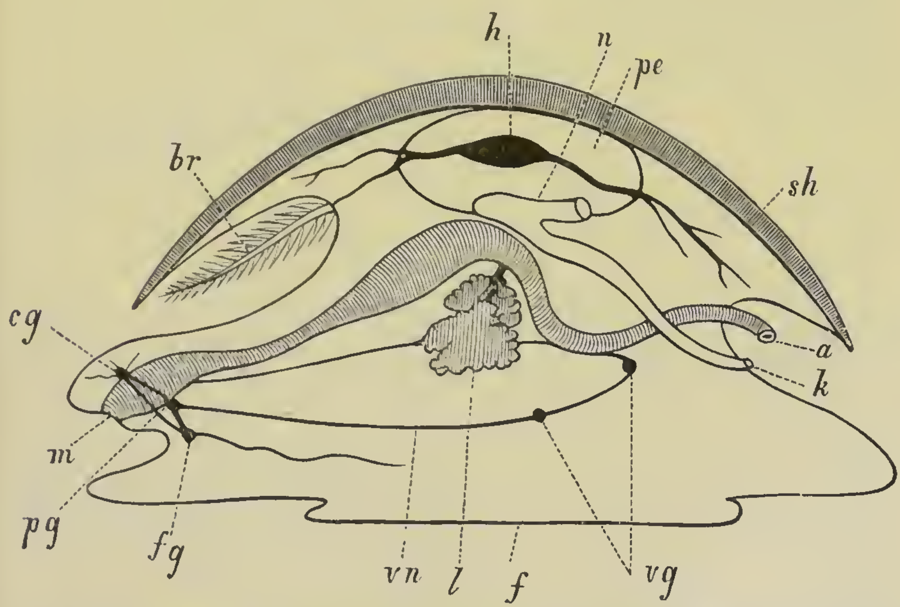

Fig. 259.—Diagram of a Mollusc (altered from Lankester). *m* Mouth; *a* Anus; *l* Liver; *f* Foot; *sh* Shell, attached to the mantle; *h* Heart; *pe* Pericardium; *n* Kidney, opening internally into the pericardium, and externally near the anus (*k*); *br* Gill; *cg* One of the cerebral ganglia, connected by commissures with the pleural ganglion (*pg*) and the pedal ganglion (*fg*); *vn* Visceral nerve-cord extending backward, and carrying visceral ganglia (*vg*).

forwards. There is a large and well-developed liver, opening into the commencement of the intestine (fig. 259, *l*).

The blood is colourless, and the blood-vessels are in part furnished with definite walls. A large part of the circulation is, however, carried on in the lacunar spaces between the tissues. A definite heart (fig. 259, *h*), consisting of a ventricle, with one or two auricles, is always present, and always has the function of propelling the aerated blood through the body. The heart lies dorsally, and is enclosed in a "pericardial chamber" (fig. 259, *pe*), which is placed in communi-

cation with the exterior by the kidneys, but is not normally filled with blood.

Respiratory organs are not always developed, the function of respiration being in some cases discharged by the thin walls of the mantle-cavity. In the majority of the Molluscs there are definite respiratory organs, a portion of the mantle being specialised for this purpose. In the *Lamellibranchiata*, and the branchiate *Gasteropoda*, the breathing-organs are in the form of lamellar and pectinate gills; and the same is the case with the *Cephalopoda*. In the pulmonate *Gasteropoda*, in which respiration is aerial, a pulmonary sac or air-chamber is produced by the folding of a portion of the mantle, over the interior of which the pulmonary vessels are distributed. The chamber thus formed communicates with the exterior by a round aperture, which can be opened or closed at will; and the renovation of the effete air within the sac appears to be effected mainly or entirely by simple diffusion.

Fig. 260.—Nervous system of a Lamellibranch (*Anodon*). *c c* Cerebral ganglia, united by a commissure in front; *p* Pedal ganglia, united with the cerebral ganglia by commissures which pass on the two sides of the gullet; *v* Visceral ganglia united to form the ".parietosplanchnic" ganglion, joined with the cerebral ganglia by the visceral commissures.

The function of excretion is especially discharged by the kidneys, which may be unpaired (Gasteropods generally). In some Gasteropods, and in the Bivalves, there are two renal organs, and in *Nautilus* there are four. The kidneys or "nephridia" of the *Mollusca* are saccular organs, which may be compared with the "segmental organs" of the Annelides. They open internally into the pericardium (fig. 259, *n*), and communicate with the exterior by a pore usually placed near the anus.

The nervous system of the *Mollusca* (fig. 260) consists of paired ganglia united by commissures. In its typical arrangement, the nervous system consists of the following parts. (1) A pair of *cerebral* ganglia (fig. 260, *c c*), joined with one another by a commissure which passes above the gullet. From the cerebral ganglia a pair of commissures

pass backwards, one on each side of the gullet, to (2) a pair of *pedal* ganglia, which supply the foot and adjacent parts with nerves. (3) A group of *visceral* ganglia placed towards the posterior part of the body. The development of these is very variable, but in the Bivalves they are of large size, and become fused to form the so-called "parieto-splanchnic" ganglion (fig. 260, *v*). In other cases the visceral ganglia are shifted forwards, and may become fused with the pedal ganglia, or with the cerebral ganglia. When separately developed, the visceral ganglia are united with the cerebral ganglia in front by a pair of visceral commissures, which may become directly connected with the cerebral ganglia, or may spring from a separate œsophageal nerve-ring, distinct from the pedal commissures. In this latter case the point of origin of the visceral commissures is marked by the development of a *pleural* ganglion on each side of the gullet (fig. 259, *pg*).

As regards their *organs of sense*, the *Mollusca* usually have tactile organs in the form of sensitive processes (labial palpi) placed round the mouth, or tentacles carried on the head. Eyes are present in many forms, and in the *Cephalopoda* reach a very high grade of organisation. In the Lamellibranchs the adults are either destitute of organs of vision, or possess numerous simple eyes ("ocelli") placed along the margins of the mantle-lobes. Auditory organs are very commonly present, and have the form of closed sacs ("otocysts"), situated either in the head or foot. There are also in some cases organs which are supposed to be olfactory in function.

Reproductive organs are always present, and the sexes may be distinct or united. The generative organs open externally near the anus, sometimes in common with the ducts of the kidneys.

As regards the *development* of the *Mollusca*, there is usually a well-marked metamorphosis. In most cases the young Mollusc passes through a stage in which the anterior part of the body, lying in front of the mouth, is furnished with a circlet of cilia, by means of which the embryo swims. In this "trochosphere" stage, the Molluscan embryo closely resembles the larvæ of many Annelides. As development proceeds, the posterior end of the body, behind the circle of cilia, grows more rapidly than the anterior end, and the latter ultimately comes to form a ciliated, often lobed disc, or "velum," on the front part of the head (fig. 261, *v*). In this stage the embryo is usually spoken of as a "veliger." In later life the ciliated velum, having discharged its temporary

purpose as a locomotive organ, usually wholly disappears. The embryo further possesses, as shown by Ray Lankester, a glandular involution of the dorsal integument, by which the

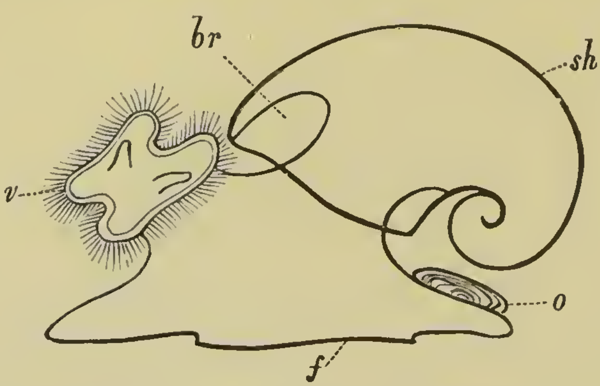

Fig. 261.—"Veliger" stage of a young Gasteropod. *v* Velum; *f* Foot; *o* Opercular plate developed on the back of the foot; *br* Branchial chamber; *sh* Primitive shell.

embryonic shell is produced, and which commonly disappears in the course of embryonic development. The shell of the adult, however, is in most cases developed secondarily from the free dorsal surface of the mantle (fig. 259, *sh*).

As implied by their scientific name, the *Mollusca* are mostly soft-bodied animals; but their popular name of "Shell-fish" expresses the fact that the presence of a shell, protecting the soft body, is likewise a very characteristic feature in the sub-kingdom. At the same time, a shell is not universally present, and many of the *Mollusca* are either permanently naked, or possess nothing that would be ordinarily looked upon as a shell. When there is either no shell at all, or merely a rudimentary shell enclosed in the mantle, the Mollusc is said to be "naked." The shell of the "testaceous" *Mollusca* is very closely related to the respiratory organs; "indeed it may be regarded as a *pneumoskeleton*, being essentially a calcified portion of the mantle, of which the breathing-organ is at most a specialised part. . . . In its most reduced form the shell is only a hollow cone or plate, protecting the breathing-organ and heart, as in *Limax*, *Testacella*, and *Carinaria*. Its peculiar features always relate to the condition of the breathing-organ, and in *Terebratula* and *Pelonaia* it becomes identified with the gill. In the *Nudibranchs* the vascular mantle performs, wholly or in part, the respiratory office. In the *Cephalopods* the shell becomes complicated by the addition of a distinct, internal, chambered portion (*phragmacone*), which is properly a *visceral* skeleton" (Woodward). In a great many of the *Mollusca*

the shell consists of but a single piece, and they are called "Univalves." In many others the shell consists of two separate plates or "valves," and these are called "Bivalves." In others, again, as in the *Chiton*, the shell consists of more than two pieces, and is said to be "multivalve." Most, however, of the multivalve shells of older writers are in reality referable to the *Cirripedia*.

All the testaceous *Mollusca* (except the Argonaut), and most of the "naked" forms, acquire a rudimentary shell before their liberation from the ovum. In the latter this rudimentary shell is cast off as the embryo grows, but in the former it becomes the "nucleus" of the adult shell. In the Bivalves the embryonic shell or "nucleus" is situated at the beak or "umbo" of each valve, and is often very unlike the remainder of the shell.

In composition the shell of the *Mollusca* consists of carbonate of lime—usually having the atomic arrangement of calcite—with a small proportion of animal matter. In the *Pholadidæ*, however, the calcareous matter exists in the allotropic condition of aragonite, which is very much harder than calcite; and there are many Gastropods in which the shell is similarly composed of aragonite. As regards their texture, three principal varieties of shells may be distinguished—viz., the "porcellanous," the "nacreous," and the "fibrous." In the "nacreous" or pearly shells, as seen in "mother-of-pearl," the shell has a peculiar lustre, due to the minute undulations of the edges of alternate layers of carbonate of lime and membrane. The "fibrous" shells are composed of successive layers of prismatic cells. The "porcellanous" shell has a more complicated structure, and is composed of three layers or strata, each of which is made up of very numerous plates, "like cards placed on edge." The direction in which the vertical plates are placed, is sometimes transverse in the central layer, and lengthwise in the two others; or longitudinal in the middle, and transverse in the outer and inner strata.

All living shells have an outer layer of animal matter, which is known as the "epidermis," or "periostracum." This is sometimes of extreme tenuity, but is sometimes very thick, the latter being especially the case with those shells which are found in fresh water.

The *Mollusca* may be roughly divided into two great sections, respectively termed the *Acephala* and the *Encephala* (or *Cephalophora*), characterised by the absence or presence of a distinctly differentiated head. The headless, or Acephalous, Molluscs correspond to the class *Lamellibranchiata;* also distinguished, at first sight, by the possession of a bivalve shell. The Encephalous Molluscs are more highly organised, and are divided into three classes—viz., the *Gastropoda*, the *Pteropoda*, and the *Cephalopoda*. The shell in these three classes is of very various nature, but they all possess a singular and complicated series of lingual teeth; hence they are grouped together by Professor Huxley under the name of *Odontophora*.

CHAPTER XXXIX.

LAMELLIBRANCHIATA.

CLASS I. LAMELLIBRANCHIATA, or CONCHIFERA (*Pelecypoda*).—The members of this class are characterised *by the absence of a distinctly differentiated head, and by having the mantle divided into two lobes, right and left, each of which secretes a shelly investment, so that the body is more or less completely enclosed in a bivalve shell. There are one or two pairs of lamellar gills on each side of the body. An odontophore is wanting. The sexes are distinct or united.*

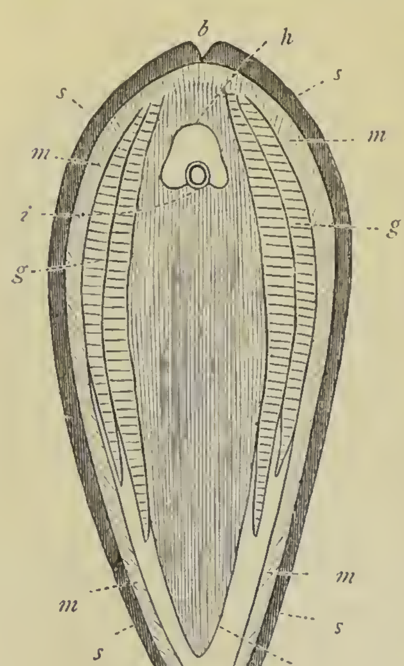

Fig. 262.—Diagrammatic vertical and transverse section of *Mya arenaria*. *b* Back, or "dorsal margin" of the shell; *s s* The two valves of the shell, right and left; *m m* The two halves, or "lobes," of the mantle, producing the shell; *g g* The gills, two pairs on each side; *h* The heart; *i* Intestine; *f* The foot.

The *Lamellibranchiata* (Mussels, Oysters, Scallops, Cockles, &c.) are often spoken of as the "Bivalve Molluscs," and they are all either marine or inhabitants of fresh water.

The body in the Lamellibranchs is bilaterally symmetrical, and is enclosed in a largely developed "mantle" or "pallium," which is divided into two lateral halves, the right and left "lobes" of the mantle. The two lobes of the mantle are united along the dorsal side of the body, and are prolonged laterally as two great flaps, which conceal the body, and enclose inferiorly a chamber known as the "mantle-cavity." The lower or ventral edges of the mantle-lobes are normally free; but in many Bivalves they become more or less fused with one another (fig. 262), so that the animal is enclosed in a complete sac, in which certain openings are left anteriorly and posteriorly. Two of these apertures are at the posterior end of the animal, and serve to permit the ingress into the mantle-cavity of the water required for respiration and for the purpose of ob-

taining food, and the egress of the same. The lower or ventral aperture is inhalant in function; the upper or dorsal aperture is exhalant; and the anus is always placed in the vicinity of the latter, so that excrementitious matters are carried away in the out-going currents of water. In many cases these two openings into the mantle-sac are drawn out into longer or shorter muscular tubes (fig. 264, *s s'*), which are known as the "siphons," and which will be more particularly considered hereafter. In those Bivalves which have the ventral margins of the mantle-lobes *free*, the in-going and outgoing currents of water still enter and leave the mantle-cavity by openings at its posterior end. The mantle-lobes, namely, present each a pair of dorsal and ventral excavations at their posterior margins, so that when the mantle-lobes are in apposition there are formed two apertures, one ventral, the other dorsal, which permit respectively the entrance and the exit of water.

In those Bivalves which have the mantle-lobes fused along their ventral edges, a third aperture is necessary in order to allow of the protrusion of the "foot" (fig. 264, *f*). This aperture is always placed ventrally and towards the anterior end of the animal. In the forms with free mantle-lobes no special opening is needed for the protrusion of this organ.

The "foot" of the Bivalves is not so extensively developed as in the Gastropods. Usually it forms a hatchet-shaped muscular organ, which may be used in locomotion, but is hardly ever adapted for crawling. In other cases it is cylindrical in shape, and in the sedentary Bivalves it is more or less completely aborted. In many cases, especially in the young, there is developed, on the under surface of the foot in the middle line, a peculiar "byssal gland." This gland secretes a viscid material which is moulded into threads by grooves on the external surface of the foot, and which gives rise to a tuft of silky fibres (the "byssus"), serving to moor the animal to foreign objects.

The *shell* of the Bivalves is the result of the deposition of lime-salts in the outer layer of the mantle, chiefly along its ventral margins; and as the mantle is divided into a right and left "lobe," so the shell also is divided into a right and left "valve." The shell is composed in general of a thin internal layer of mother-of-pearl, and an outer prismatic layer, the component prisms being at right angles to the general surface of the shell; but the minute structure varies in different types of the class. The external surface of the shell is covered, as a rule, by a horny "epidermis," but this may

be wanting in the adult. Each valve, moreover, shows more or less numerous concentric "lines of growth," indicating the periodic additions made to the ventral margin of the shell.

Though the Bivalves agree with the *Brachiopoda* in possessing a shell which is composed of two pieces or valves (small accessory plates are present in *Pholas*, &c.), there are, nevertheless, many points in which the shell of a Lamellibranch is distinguished from that of a Brachiopod, irrespective of the great difference in the structure of the animal in each. The shell in the *Brachiopoda*, as we have seen, is rarely or never quite equivalve, and always has its two sides equally developed (equilateral); whilst the valves are placed antero-posteriorly as regards the animal, one in front and one behind, so that they are "dorsal" and "ventral." In the *Lamellibranchiata*, on the other hand, the two valves are usually of nearly equal size (equivalve), and are more developed on one side than on the other (inequilateral); whilst their position as regards the animal is always *lateral*, so that they are properly termed "right" and "left" valves, instead of "ventral" and "dorsal."

It is to be remembered, however, that many of the Bivalves, such as the Oysters, habitually lie on one side, in which case the valves, though really right and left, are called "upper" and "lower." It is to be borne in mind, also, that the two valves, especially in the attached Bivalves, may be very unsymmetrical, one valve being much larger or deeper than the other. Lastly, there are some cases (*e.g.*, *Pectunculus*) in which the shell becomes very nearly equilateral, the line drawn from the beaks to the base dividing the shell into two almost equal halves.

The following are the chief points to be noticed in connection with the shell of any Lamellibranch (fig. 263): Each valve of the shell may be regarded as essentially a hollow cone, the apex of which is turned more or less to one side; so that more of the shell is situated on one side of the apex than on the other. The apex of the valve is called the "umbo," or "beak," and is mostly turned towards the mouth of the animal. Consequently, the side of the shell towards which the umbones are turned is the "anterior" side, and it is usually the shortest half of the shell. In some Bivalves, however, the beaks are "reversed," and are turned towards the posterior side of the shell. The longer half of the shell, from which the umbones turn away, is called the "posterior" side, but in some cases this is equal to, or even shorter than, the anterior side. The side of the shell where the beaks are situated, and where the

valves are united to one another, is called the "dorsal" side; and the opposite margin, along which the shell opens, is called the "ventral" side or "base." The *length* of the shell is

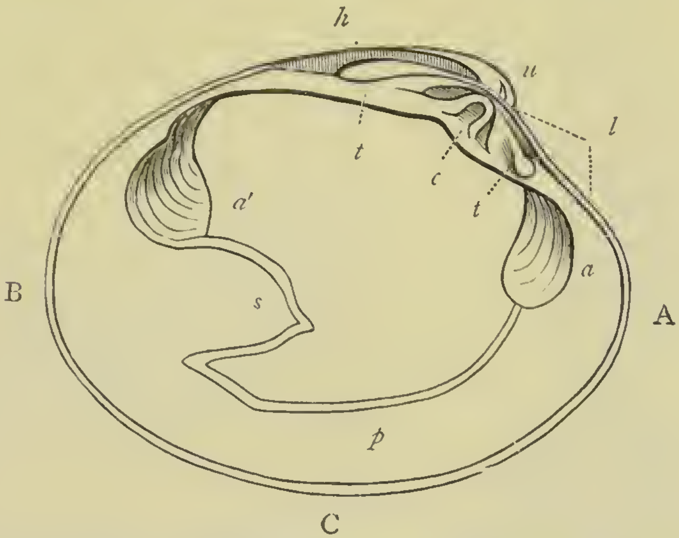

Fig. 263.—Left valve of *Cytherea chione*. (After Woodward.) A, Anterior margin. B, Posterior margin. C, Ventral margin or base: *u* Umbo; *h* Ligament; *l* Lunule; *c* Cardinal tooth; *t t* Lateral teeth; *a* Anterior adductor; *a'* Posterior adductor; *p* Pallial line; *s* Pallial sinus, caused by the retractor muscles of the siphons.

measured from its anterior to its posterior margin, and its *breadth* from the dorsal margin to the base.

At the dorsal margin the valves are united to one another, for a shorter or longer distance, along a line which is called the "hinge-line." The union is effected in most shells by means of a series of parts which interlock with one another (the "teeth"), but these are sometimes absent, when the shell is said to be "edentulous." Posterior to the umbones, in most Bivalves, is another structure passing between the valves, which is called the "ligament," and which is usually composed of two parts, either distinct or combined with one another. These two parts are known as the "external ligament" (or the ligament proper) and the "cartilage," and they constitute the agency whereby the shell is opened, but one or other of them may be absent. The ligament proper is outside the shell, and consists of a band of horny fibres, passing from one valve to the other just *behind* the beaks, in such a manner that it is put upon the stretch when the shell is closed. The cartilage, or internal ligament, is lodged between the hinge-lines of the two valves, generally in one or more "pits," or in special processes of the shell. It consists of elastic fibres placed perpendicu-

larly between the surfaces by which it is contained, so that they are necessarily shortened and compressed when the valves are shut. To open the shell, therefore, it is simply necessary for the animal to relax the muscles which are provided for the closure of the valves, whereupon the elastic force of the ligament and cartilage is sufficient of itself to open the shell.

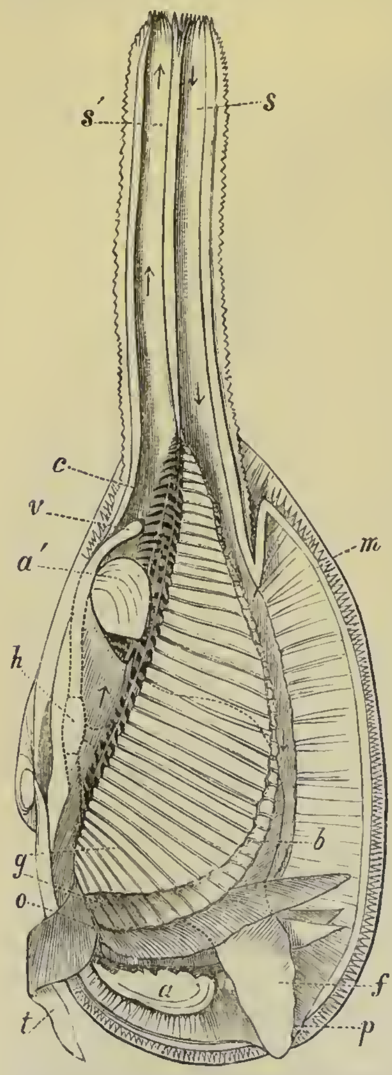

Fig. 264.—Anatomy of *Mya arenaria*. (After Woodward.) The left valve of the shell and the left mantle-lobe are removed, and half of the siphons has been cut away. *a* Anterior adductor; *a'* Posterior adductor; *b* Visceral mass; *c* Chamber of the mantle-cavity into which the anus (*v*) opens; *f* Foot; *g* Branchiæ; *h* Heart; *m* Cut ventral edge of the mantle; *o* Mouth; *s* Inhalant siphon; *s'* Exhalant siphon. *t* Labial palpi. The arrows indicate the direction of the water-currents.

Generally the hinge-line is curved, but it is sometimes straight. The beaks are mostly more or less contiguous, but they may be removed from one another to a greater or less distance, and in some anomalous forms they are not near one another at all. In the *Arcadæ* the two beaks are separated from one another by an oval or lozenge-shaped flat space or area. When teeth are present, they differ much in their form and arrangement. In some forms (fig. 263) the teeth are divisible into three sets—one group, of one or more teeth, placed immediately beneath the umbo, and known as the "cardinal teeth"; and two groups on either side of the preceding, termed the "lateral teeth." Sometimes there may be lateral teeth only; sometimes the cardinal teeth alone are present; and in some cases (*Arcadæ*) there is a row of similar and equal teeth.

While the opening of the valves of the shell of a Lamellibranch is effected by the elastic force of the ligament, the closure of the valves is effected by the contraction of one or two powerful muscles, which are known as the "adductor muscles." In the majority of Bivalves—hence termed

Dimyaria—there are two adductor muscles, which pass from the inner surface of one valve to that of the other, one being placed anteriorly in front of the mouth, while the other is situated posteriorly close to the termination of the intestine (fig. 264, *a* and *a'*). Moreover, among the Dimyary Bivalves the adductors present two markedly different conditions. In one group of forms—hence termed *Homomyaria*—the anterior and posterior adductors are approximately equal in size. In a second series—hence termed *Heteromyaria*—the anterior adductor is very small, and the posterior adductor is very large. Examples of this latter condition are found in the Mussels, Pearl-mussels, &c. On the other hand, in *Ostrea*, *Pecten*, and certain other Bivalves—hence called *Monomyaria*—the anterior adductor is absent, and the posterior adductor alone remains. The adductors leave distinct "muscular impressions" in the interior of the shell (fig. 265), so that it is easy to determine, by a simple inspection of the dead shell, whether a given Bivalve has been "dimyary" or "monomyary."

Besides the scars left by the adductor muscles, or muscle, there are other impressions in the interior of the valves which are produced by the attachment of muscles. Thus, the "foot" is very commonly provided with "pedal muscles," which leave small scars in the inside of the shell. When they are well developed, the "pedal impressions" are twofold, consisting of an impression formed by the "protractor" muscle which exserts the foot, and of another, posteriorly-placed scar (sometimes two such) formed by the "retractor" muscle which withdraws the foot (fig. 265, A, *pp* and *rp*).

Again, the muscular margin of the mantle is attached to the interior of each valve along a line running at a little distance within, and parallel with, the ventral margin of the shell. In this way is formed a more or less well-marked impression in the interior of each valve, which is termed the "pallial line" (fig. 265, *m*). The form assumed by the "pallial line" differs in different Bivalves according as respiratory "siphons" are present or absent. In all those Bivalves, namely, in which the mantle-lobes are free, and in which there are consequently no siphons, the "pallial line" runs in an unbroken curve round the lower part of the valve (fig. 265, A, *m*). The pallial line is similarly unbroken in those Bivalves which possess short siphons, but which do not possess a specially developed "retractor muscle" for the withdrawal of the siphons within the shell. The name of *Integropallialia* is given to all such Bivalves as the above, in which the pallial line is "entire," or unindented, and there are either no siphons or but short ones.

On the other hand, in those Bivalves which have long respiratory siphons there exists a specially developed "retractor muscle," the function of which is to withdraw the siphons within the shell. The insertion of this siphonal retractor causes an indentation in the pallial line posteriorly (fig. 265,

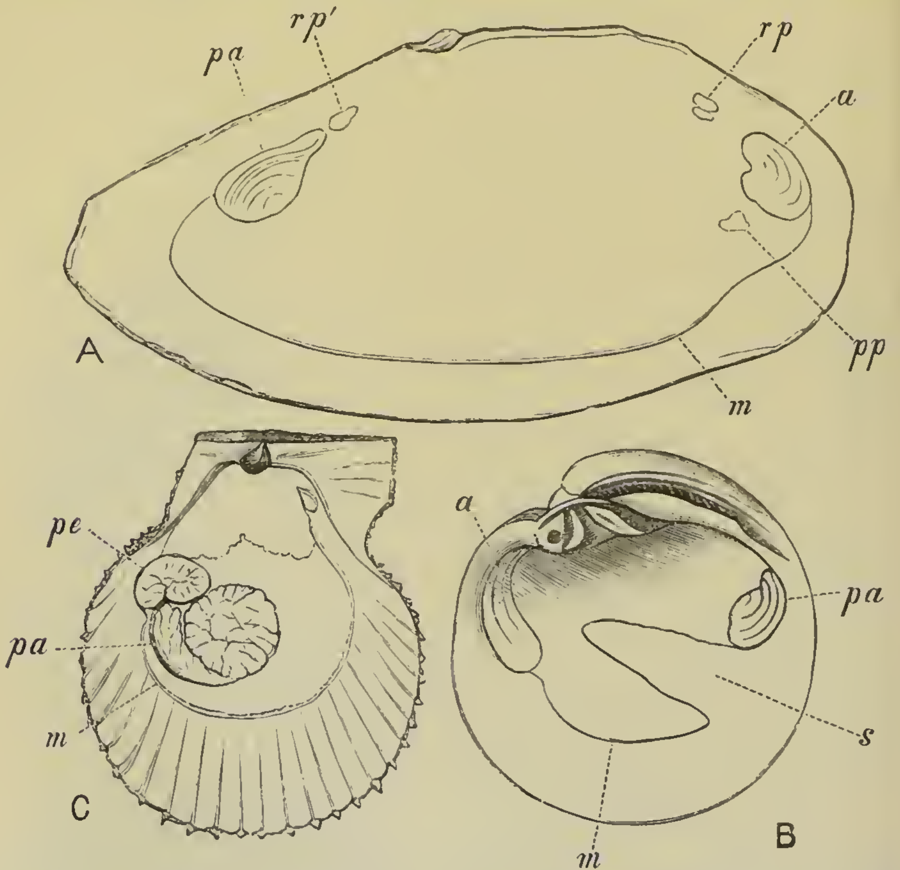

Fig. 265.—A, Interior of the left valve of *Anodonta cygnea*. B, Interior of the right valve of *Artemis exoleta* (after Woodward). C, Interior of the left valve of *Pecten varius* (after Woodward). *a* Impression of the anterior adductor; *pa* Impression of the posterior adductor; *m* Pallial line; *s* Sinus in the pallial line caused by the insertion of the retractor muscles of the siphons; *pp* Scar of the protractor muscle of the foot; *rp* Scar of the anterior retractor muscle of the foot; *rp′* Scar of the posterior retractor muscle of the foot. In *Pecten varius* (C), though the shell is monomyary, the scar left by the posterior adductor (*pa*) is double, and there is a large scar (*pe*) formed by the muscular base of the foot.

B, *s*), the depth of this depending upon the size of the siphonal muscles. In all those Bivalves, therefore, which possess retractile siphons, the pallial line is deflected posteriorly into a larger or smaller "pallial sinus" or siphonal impression," and those Bivalves in which this sinus exists are grouped together under the name of *Sinupallialia*.

There is no distinctly differentiated head in any of the

Lamellibranchs (hence the name of "Acephalous Molluscs" commonly given to the class), and the mouth is simply placed at the anterior end of the body. It is furnished with ciliated, leaf-like, membranous processes, or "labial palpi" (fig. 266, *lp*), which are two or four in number, and serve as organs of touch.

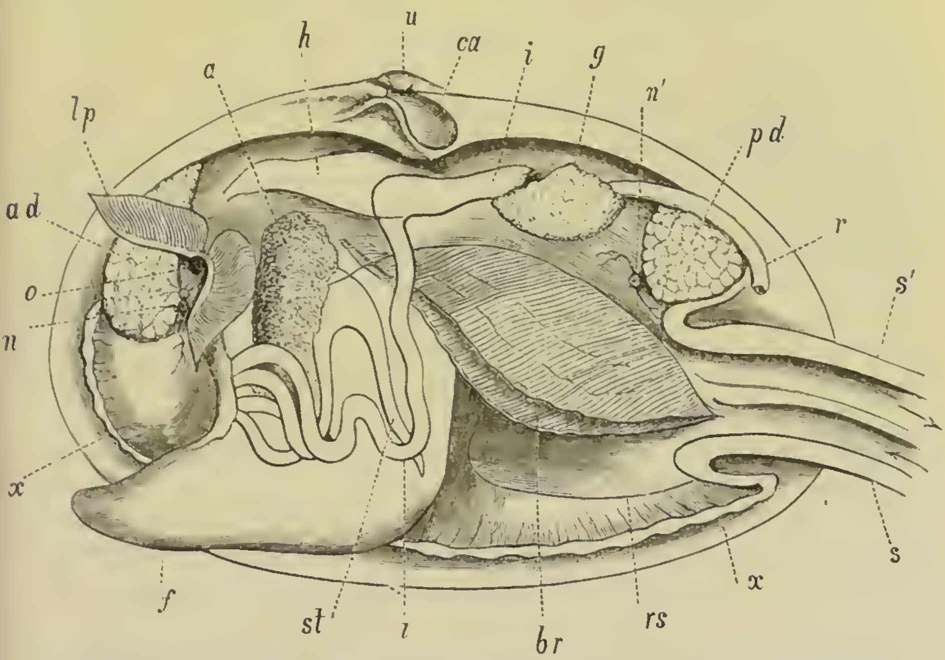

Fig. 266.—Lamellibranchiata. Diagrammatic representation of the anatomy of a siphonate Bivalve. The left valve and left mantle-lobe are removed, and the siphons are cut short. *u* Umbo; *ca* Cartilage-pit; *o* Mouth; *lp* Labial palpi; *a* Stomach, surrounded by liver; *st* Sac containing the crystalline stylet; *i i* Intestine, perforating the heart (*h*); *r* Rectum, terminating in the anus; *ad* Anterior adductor; *pd* Posterior adductor; *n* Supra-œsophageal or cerebral ganglion (the mouth is a little displaced upwards, so that the ganglion comes to lie below the gullet instead of above it); *n'* Parietosplanchnic or branchial ganglion; *f* Foot; *x x*, Cut edge of the right mantle-lobe; *rs* Retractor muscle of the siphons; *br* Branchiæ of the left side; *g* Generative glands; *s* Inhalant siphon; *s'* Exhalant siphon.

The food consists of microscopic organisms or particles of broken-down animal or vegetable matter, which enter the mantle-cavity in the in-going currents of water, and are driven by ciliary action along a groove formed by the lower edges of the branchiæ till they reach the mouth. No dental apparatus of any kind is developed, and the mouth opens into a gullet, which conducts to a distinct stomach. On the right side of the stomach, and opening into it, is, in many cases, a blind sac containing a peculiar transparent glassy body, which is known as the "crystalline stylet," but the functions of which are unknown. This singular structure is generally wanting in

the Monomyary Bivalves. The intestine is long and coiled, and is surrounded by the spongy, brownish, or greenish liver, and by the generative glands. In the final part of its course, the intestine is situated dorsally, and (except in *Ostrea*, *Anomia*, *Teredo*, and *Arca*) perforates the ventricle of the heart. It finally passes dorsally to the posterior adductor muscle (fig. 266, *r*), and ends in a distinct anus, placed near the point where the out-going currents of water are expelled from the mantle-cavity.

The heart of the Bivalves (fig. 266, *h*) is situated dorsally, within a membranous chamber, which is termed the "pericardium," but which is not filled with blood. Typically, the heart consists of a single central ventricle into which the blood is propelled by two laterally-placed auricles. The ventricle distributes the arterialised blood by means of aortic vessels, the branches of which open into the lacunæ between the tissues. The venous blood ultimately reaches the gills, where it is aerated, and the blood thus oxygenated is finally returned to the auricles.

The respiratory organs in all the *Lamellibranchiata* consist of lamelliform gills attached by their bases to the sides of the body, and hanging freely in the mantle-cavity (figs. 262, *g*, 263, *g*, and 266, *br*). Ordinarily there are two of these leaf-like gills on each side of the body, but in some Bivalves the external pair of branchiæ is absent. Each gill consists of two laminæ (an ascending and descending lamina) united along the free margin of the gill, but slightly separated superiorly. Each lamina consists of hollow filaments placed parallel to one another, and running continuously from one lamina to the other. Adjoining filaments are kept in contact with one another by means of interlocking cilia ("ciliated junctions") developed at corresponding points on their sides. Moreover, the filaments of the descending lamella of the gill are connected with those in the ascending lamella by means of hollow cross-bars. The blood circulates through the hollow filaments of the branchiæ, which thus form a kind of ciliated grating through and over which the water is driven.

As has been already mentioned, the arrangements for the admission of water to the gills, and its expulsion again from the mantle-cavity, are essentially the same in all Bivalves. In all cases the in-going current of water enters the pallial chamber posteriorly and ventrally, while the out-going current escapes posteriorly and dorsally. In those Bivalves which have free mantle-lobes ("Asiphonate Bivalves"), the apertures for the water-currents are simply produced by the apposition of

the hinder edges of the mantle-lobes to each other. On the other hand, in those Bivalves which have the mantle-lobes united ("Siphonate Bivalves," fig. 264), the margins of the "inhalant" and "exhalant" apertures are drawn out or extended into longer or shorter muscular tubes or "siphons." The siphons may be separate, or they may be united to one another along one side, and they can usually be partially or entirely retracted within the shell by means of special muscles, called the "retractor muscles of the siphons." These siphons are more specially characteristic of those Lamellibranchs which spend their existence buried in the sand, protruding their respiratory tubes in order to obtain water, and with it such nutrient particles as the water may contain. As has been previously seen, the presence or absence of retractile siphons can be readily determined merely by inspection of the dead shell.

The kidney or "nephridium" of the Bivalves is usually spoken of as the "organ of Bojanus," and has the form of an elongated double sac, of which there is one on each side, placed just below the pericardium, and separated by a venous sinus. The upper portion of the "organ of Bojanus" is non-glandular, and opens into the pericardium; while its lower portion is glandular, and gives origin to a duct which opens into the mantle-cavity posteriorly, often along with the ducts of the generative glands.

The nervous system consists of the three normal pairs of ganglia,—the "cerebral," "pedal," and "parietosplanchnic" or "visceral" ganglia. The "cerebral" ganglia are placed one on either side of the mouth, often at some distance from one another; the "pedal" ganglia are placed in the substance of the foot, a little above its ventral margin anteriorly; and the "parietosplanchnic" ganglia are usually amalgamated to form a bilobed mass, which is situated on the ventral face of the posterior adductor muscle. The principal organs of sense are the tactile labial palpi, otocysts, and eye-spots. The otocysts, when present, are placed below the gullet; and the ocelli (which are often wanting) are generally situated round the margins of the mantle-lobes.

The majority of the Bivalves are diœcious, but a few forms (*Ostrea*, *Pecten*, *Cyclas*, &c.,) have the sexes united in the same individual. The generative glands are usually in the form of lobed or racemose glands, more or less closely united with the hepatic glands, and surrounding the intestine or extending into the foot. The ducts of the generative organs either join the ducts of the "organ of Bojanus," or open

separately in the immediate neighbourhood of the nephridial pores. The impregnated ova are commonly hatched within the pallial chamber of the parent, and the embryos are often retained therein, until development has become considerably advanced. Except in the fresh-water Lamellibranchs, the embryo generally exhibits a "trochosphere" stage, having a well-developed ciliated ring, or "velum" (fig. 267), by means of which it swims about actively.

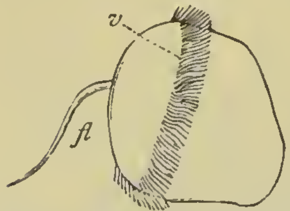

Fig. 267.—Embryo of Cockle (*Cardium*), after Lovén. *v* Ciliated velum; *fl* Flagellum.

The habits of the *Lamellibranchiata* are very various. Some, such as the Oyster (*Ostrea*), and the Scallop (*Pecten*), habitually lie on one side, the lower valve being the deepest, and the foot being wanting, or rudimentary. The former is fixed by the substance of the valve, but the latter swims by rapidly opening and closing the shell. Others, such as the Mussel (*Mytilus*) and the *Pinna*, are attached to some foreign object by a "byssus." Others are fixed to some solid body by the substance of one of the valves. Many, such as the *Myas*, spend their existence sunk in the sand of the sea-shore or in the mud of estuaries. Others, as the *Pholades* and *Lithodomi*, bore holes in rock or wood, in which they live. Finally, many are permanently free and locomotive.

The *Lamellibranchiata* may be divided into two sections, according as respiratory siphons are absent or present, as follows:—

SUB-CLASS A. ASIPHONIDA. — Animal without respiratory siphons; mantle-lobes free; pallial line simple and not indented (*Integropallialia*).

The principal families included in this section are the *Ostreidæ*, *Aviculidæ*, *Mytilidæ*, *Arcadæ*, *Trigoniadæ*, and *Unionidæ*.

The *Ostreidæ* (including the Oysters, Scallops, *Anomiæ*, Thorny Oysters, &c.) are all marine, and are monomyary. The *Aviculidæ*, or Pearl-oysters, are likewise marine, but are dimyary. The *Mytilidæ* (Mussels, Horse-mussels, &c.) are partially marine and partially fresh-water forms, and have a very small anterior adductor. The *Arcadæ* (Ark-shells, &c.) are exclusively marine, as are the nearly allied *Trigoniadæ*. Lastly, the *Unionidæ* (Fresh-water Mussels) are exclusively confined to rivers and lakes.

SUB-CLASS B. SIPHONIDA.—Animal with respiratory siphons; mantle-lobes more or less united.

Two subdivisions are comprised in this section. In the first *the siphons are short, and the pallial line is simple* (*Integ-*

ropallialia); as is seen in the families *Chamidæ*, *Hippuritidæ*, *Tridacnidæ*, *Cardiadæ*, *Lucinidæ*, *Cycladidæ*, and *Cyprinidæ*.

The second subdivision (*Sinupallialia*) is distinguished by the possession of *long respiratory siphons*, and a *sinuated pallial line*, and it comprises the families *Veneridæ*, *Mactridæ*, *Tellinidæ*, *Solenidæ*, *Myacidæ*, *Anatinidæ*, *Gastrochænidæ*, and *Pholadidæ*.

The *Chamidæ* (Thorny Clams) are fixed to foreign bodies by the substance of either valve indifferently, and are all inhabitants of the sea. The extraordinary extinct group of the *Hippuritidæ*, from the fossils associated with them, are known to have been also marine; and they are often found in great beds like Oysters, attached to one another and to foreign objects by the beak of the right valve. The *Tridacnidæ* (Giant Clams) have a similar habitat, and the shell may attain a weight of five hundred pounds. The *Cardiadæ* (Cockles) and *Lucinidæ* are also marine, as are the *Cyprinidæ*; but the *Cycladidæ* are fresh-water and brackish-water forms. The *Veneridæ* (Clams) are amongst the most beautiful of the Bivalves, and are found in all seas, attaining their maximum in warm regions. The *Mactridæ* (Trough-shells) and *Tellinidæ* are mostly marine, though also found in brackish waters; and the *Solenidæ* (Razor-shells), *Myacidæ*, and *Anatinidæ* are essentially marine, though some of the *Myacidæ* extend their range for a considerable distance above the mouths of rivers. The *Gastrochænidæ* are all natives of the sea, and have a burrowing habit, boring holes for habitation in rocks, or living in the mud. Lastly, the *Pholadidæ* (Piddocks and Ship-worms) bore holes in stone or wood, in which they live, and are all marine in habit. The Ship-worms (*Teredo*) have long worm-like bodies, and do an immense amount of harm by honeycombing with their burrows the sides of ships, or other wooden structures immersed in the sea.

As regards their *distribution in time*, the Lamellibranchs are a very ancient group, the earliest representatives of the class being found in the Cambrian rocks. Upon the whole, the Asiphonate Bivalves are more characteristically Palæozoic, while those in which the mantle-lobes are united and there are respiratory siphons, are principally found in the Secondary and Tertiary rocks. One of the principal Palæozoic groups is that of the *Aviculidæ*, while the *Mytilidæ* are also largely represented. Monomyary types appear in the later portion of the Palæozoic period, numerous forms (*Aviculopecten*, &c.) allied to the recent Scallops occurring in the Carboniferous rocks. With the commencement of the Secondary period, in the Trias, many old types disappear, and new ones take their places. Monomyary Bivalves are now numerous, but among the Dimyary forms the Asiphonate families still predominate. The forms with long retractile siphons (*Sinupallialia*) begin with a few types in the Trias, and gradually become more numerous as we pass upwards. The *Veneridæ*, which are

perhaps the most highly organised of the groups of the Lamellibranchs, appear for the first time in the Jurassic rocks, and increasing in the Tertiaries, have culminated in the Recent period. The singular group of the *Hippuritidæ* is exclusively confined to the Cretaceous period.

CHAPTER XL.

GASTROPODA, POLYPLACOPHORA, AND SCAPHOPODA.

DIVISION ENCEPHALA, or CEPHALOPHORA.—The remaining three classes of the Mollusca all possess a distinctly differentiated head, and all are provided with a peculiar masticatory apparatus, which is known as the "odontophore." For the first of these reasons they are often grouped together under the name *Encephala;* and for the second reason they are united into a common division under the name of *Odontophora* (Huxley), or *Glossophora* (Lankester).

CLASS II. GASTROPODA (or GASTEROPODA).

The members of this class are *Mollusca with a more or less distinct head, and a generally unsymmetrical body. The mantle is never divided into two lobes, and the shell, when present, is usually univalve (multivalve in Chitonidæ). The "foot" is well developed, and usually has the form of a broad horizontally-flattened ventral disc, upon which the animal creeps. Rarely, the foot is in the form of a vertically-flattened, ventral, fin-like organ.*

The body in the Gastropods is composed of three principal portions—a head, foot, and visceral sac—the last of these being more or less completely protected by a fold of the dorsal integument constituting the "mantle." Except in the Chitons, the body is distinctly unsymmetrical, and the mantle is never divided into a right and left lobe, while the visceral sac is often coiled up spirally. The foot is typically in the form of a broad flattened muscular disc, developed upon the ventral surface of the body, and not exhibiting any distinct division into parts. In the *Heteropoda*, however, and in the Wing-shells (*Strombidæ*), the foot exhibits a division into three

portions: an anterior, the "propodium"; a middle, the "mesopodium"; and a posterior lobe, or "metapodium." In the *Heteropoda*, the foot is flattened, and forms a ventral fin, by means of which the animal swims, back downwards.

Fig. 268.—*Ampullaria canaliculata*, one of the Apple-shells. *o* Operculum; *s* Respiratory siphon.

In some, again, the upper and lateral surfaces of the foot are expanded into muscular side-lobes, which are called "epipodia." In many cases the metapodium, or posterior portion of the foot, secretes a calcareous, horny, or fibrous plate, which is called the "operculum" (fig. 269, *o*), and which serves to close the orifice of the shell when the animal is retracted within it.

The *shell* of the Gastropods is a secretion from the mantle, and is always present in the embryo. It is, however, wanting in the adults of the Nudibranchs and in some other forms, and it is in other cases very minute, and hidden in the mantle (as, for example, in the Slugs). From the very general occurrence of a shell which is "univalve," or composed of a single piece, the Gastropods are commonly spoken of as the "Univalve Molluscs." In the Chitons (*Polyplacophora*), however, the shell is "multivalve," and consists of eight plates arranged in a longitudinal series. In its chemical composition the shell is composed of carbonate of lime (sometimes in the condition of calcite, sometimes in that of aragonite). Its inner layer is often nacreous, and it grows by additions made to its free margin by the muscular edge ("collar") of the mantle, in which numerous pigment-glands are contained. Primitively the shell is covered with a cuticular horny layer ("epidermis"), but this often disappears with age. In many cases, the mantle becomes reflected over the shell, the outer surface

of which may thus become covered with a layer of enamel (as in the Cowries).

The ordinary univalve shell of the Gastropods is to be regarded as essentially a cone, the apex of which is more or less oblique. In the simplest form of the shell, the conical shape is retained without any alteration, as is seen in the common Limpet (*Patella*). In the great majority of cases, however, the cone is considerably elongated, so as to form a tube, which may retain this shape (as in *Dentalium*), but is usually coiled up into a spiral. The "spiral univalve" (figs. 269, 270) may,

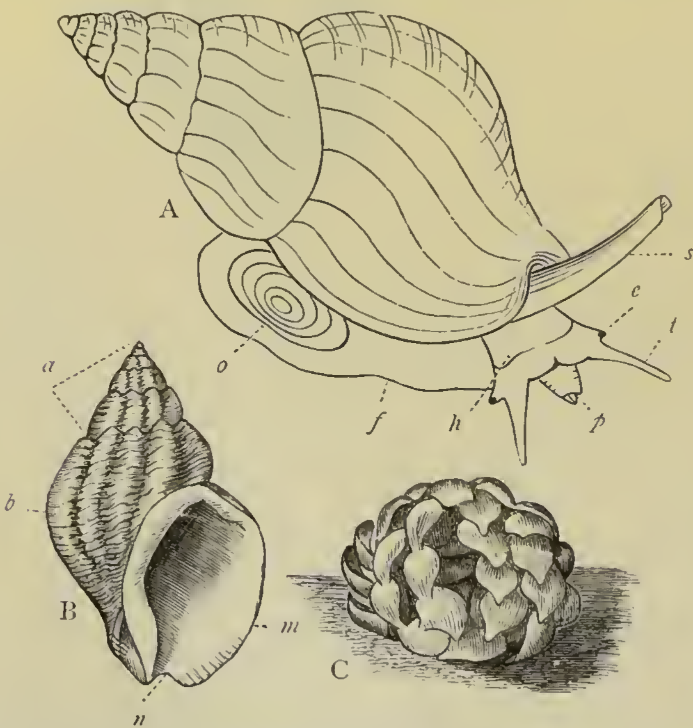

Fig. 269.—A, Sketch of a Whelk (*Buccinum undatum*) in motion: *f* Foot; *h* Head carrying the feelers (*t*), with the eyes (*c*) at their bases; *p* Proboscis; *s* Respiratory siphon, or tube by which water is admitted to the gills; *o* Operculum. B, Shell of the Whelk: *a* Spire; *b* Body-whorl; *n* Notch in the front margin of the mouth of the shell; *m* Outer lip of the mouth of the shell. This figure is half the natural size. C, A small cluster of the egg-capsules of the Whelk. (B and C are after Woodward.)

in fact, be looked upon as the typical form of the shell in the *Gastropoda*. In some cases the coils of the shell—termed technically the "whorls"—are hardly in contact with one another (as in *Vermetus*). More commonly the whorls are in contact, and are so amalgamated that the inner side of each convolution is formed by the pre-existing whorl. In some cases the whorls of the shell are coiled round a central axis *in*

the same plane, when the shell is said to be "discoidal" (as in the common fresh-water shell *Planorbis*). In most cases, however, the whorls are wound round an axis in an oblique manner, a true spiral being formed, and the shell becoming "turreted," "trochoid," "turbinated," &c. This last form is the one which may be looked upon as most characteristic of the Gastropods, the shell being composed of a number of whorls passing obliquely round a central axis or "columella," having the embryonic shell or "nucleus" at its apex, and having the mouth or "aperture" of the shell placed at the extremity of the last and largest of the whorls, termed the "body-whorl" (fig. 269). The lines or grooves formed by the

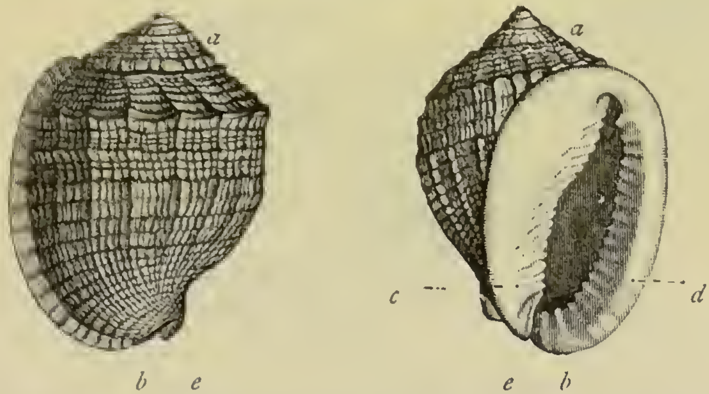

Fig. 270.—Anterior and posterior views of *Cassis cancellata*, a spiral Gastropod. *a* "Spire," placed at the posterior end of the shell; *b* "Mouth," placed at the anterior end of the shell; *c* Inner or columellar lip; *d* Outer lip; *e* Notch for the passage of a respiratory siphon.

junction of the whorls are termed the "sutures," and the whorls above the body-whorl constitute the "spire" of the shell. The axis of the shell (columella) round which the whorls are coiled is usually solid, when the shell is said to be "imperforate"; but it is sometimes hollow, when the shell is said to be "perforated," and the aperture of the axis near the mouth of the shell is called the "umbilicus." The margin of the "aperture" of the shell is termed the "peristome," or "peritreme," and is composed of an outer and inner lip, of which the former is often expanded or fringed with spines. When these expansions or fringes are periodically formed, the place of the mouth of the shell at different stages of its growth is marked by ridges or rows of spines, which cross the whorls, and are called "varices." In most of the phytophagous Gastropods (*Holostomata*) the aperture of the shell (fig. 273) is unbrokenly round or "entire," but in the carnivorous forms

(*Siphonostomata*) it is notched, or produced into a canal (fig. 269). Often there are two of these canals, an anterior and a posterior, but they do not necessarily indicate the nature of the food, as their function is to protect the respiratory siphons. The animal withdraws into its shell by a retractor muscle, which passes into the foot, or is attached to the operculum; its scar or impression being placed, in the spiral Univalves, upon the columella. In the great majority of the Univalves

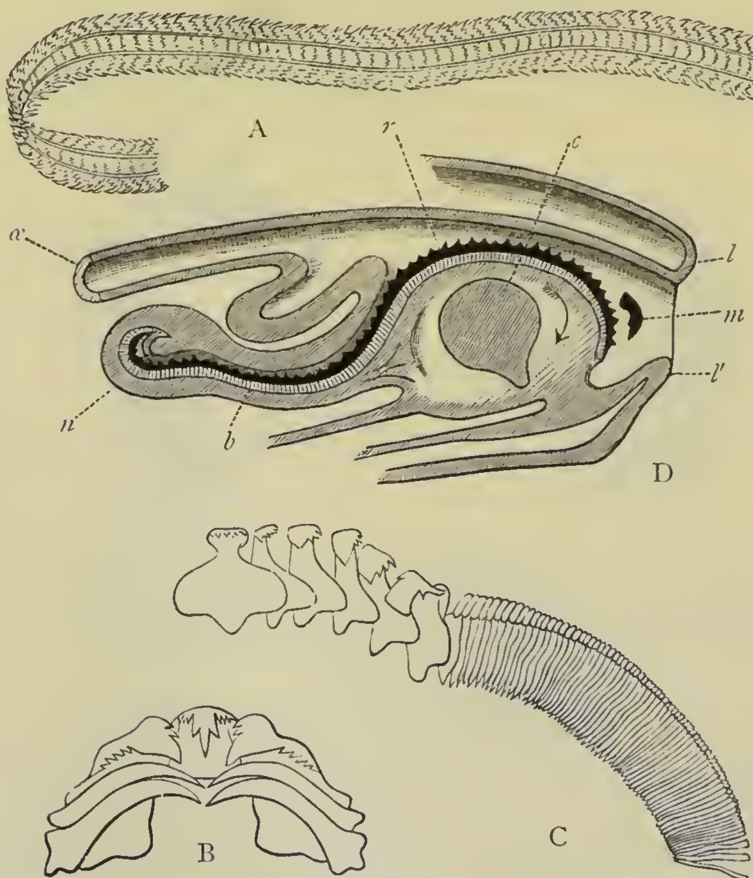

Fig. 271.—A, Radula of the Whelk (*Buccinum undatum*), enlarged. B, One row of the lingual teeth of *Cypræa europæa*. C, Lingual teeth of *Trochus cinerarius*, showing the median row and the teeth on one side of this. D, Section of the odontophore of a Gastropod: *l* Upper lip; *l'* Lower lip; *æ* Œsophagus cut through longitudinally; *m* One of the horny mandibles; *r* Radula or lingual ribbon; *n* Posterior end of the secreting sac in which the radula is produced; *b* Layer of cells forming the bed of the radula; *c* Cartilaginous piece developed in the floor of the pharynx, and serving for the support of the radula and for the attachment of the muscles which work it. The arrow shows the direction in which the radula is moved. (A, B, and C are after S. P. Woodward. D is after Ray Lankester).

the shell is coiled to the left, the "mouth" of the shell being thus on the right-hand side (fig. 270). In such cases the shell is said to be right-handed or "dextral." In other cases,

however, the shell is coiled to the right, and the mouth is on the left, and the shell becomes "reversed" or "sinistral." The left-handed spiral may be the normal condition of the shell, or it may be only a variety of a normally dextral form.

As regards their internal anatomy, the head of the Gastropods is usually very distinctly marked out, and is generally provided with tentacles and eyes. Very often, there is an elongated retractile proboscis, with ear-sacs, containing otoliths, at its base. The mouth opens at the front of the head, and leads into a buccal cavity or pharynx, into which salivary glands pour their secretion (fig. 272, *n*). The upper wall of

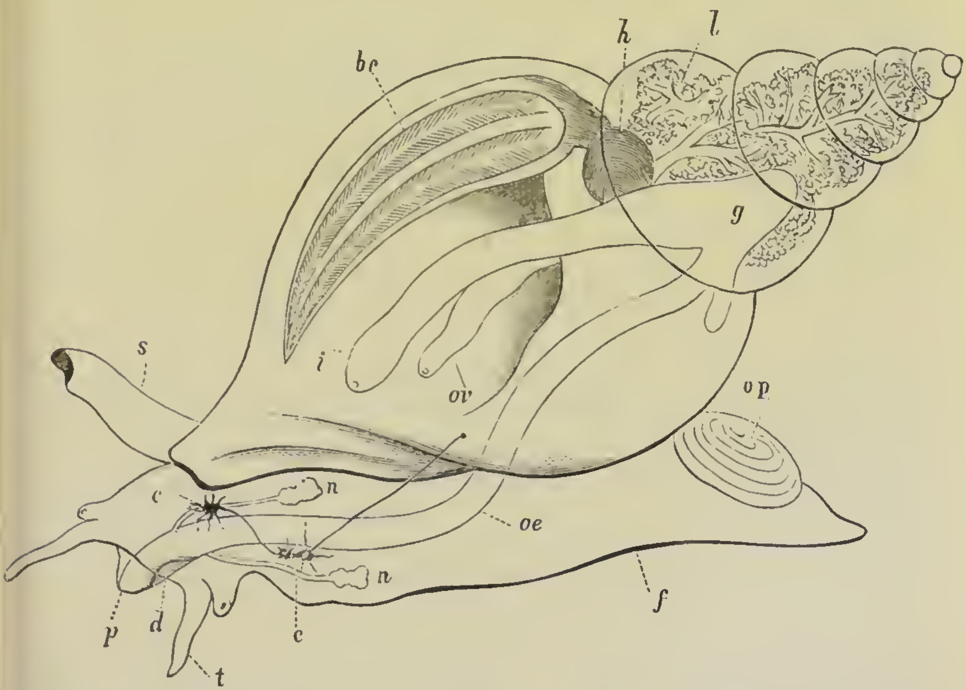

Fig. 272.—Diagram of the structure of a Gastropod (the Common Whelk). *f* The muscular "foot"; *op* The operculum; *t* One of the tentacles, or feelers, with an eye at its base; *p* The proboscis, retracted, with the mouth at its extremity; *oe* Gullet; *g* Stomach; *i* Intestine, terminating in the anus; *n n* Salivary glands; *l* The liver and the ovary; *ov* Oviduct; *h* The heart; *bc* The gill, contained in a hood of the mantle; *s* Breathing-tube or siphon; *c* and *c* The main nerve-ganglia.

the pharynx very generally carries horny jaws, in the form of two lateral mandibles or of a median plate. Within the pharynx is also found the singular masticatory apparatus known as the "odontophore" (fig. 271). This is a tubular involution of the ventral side of the pharynx in the middle line, in which is developed a chitinous band, which is beset with minute transversely-arranged teeth, and is known as the "radula" or "lingual ribbon" (fig. 271, D). The arrangement of the teeth

differs greatly in different cases, but they are usually disposed in a principal median series, flanked by two or more lateral rows (fig. 271, A, B, C); and their form and disposition are so constant as to afford one of the most valuable aids to the classification of the Gastropods. The radula is supported in front by a cartilaginous cushion (fig. 271, D, *c*) developed in the floor of the pharynx, and this cushion can be brought forward or retracted by special muscles. In this way the radula can be made to act like a file, rasp, or chain-saw. In other cases, the whole sac in which the lingual ribbon is contained can be made by muscular action to move backwards and forwards over its supporting cushion. The wear and tear of the radula in front is compensated for by the continued growth of the hinder end of the ribbon in its secreting sac.

The gullet leads into a well-marked stomach (fig. 272, *g*), and the intestine, which is often long and much coiled, terminates by a distinct anus, which is usually placed anteriorly on the right side of the neck. In the Chitons the aperture of the anus is posterior. There is usually a large and well-developed liver, the lobes of which surround the intestine (fig. 272, *l*), and occupy the upper part of the visceral sac.

The heart of the Gastropods (fig. 272, *h*) is situated dorsally, and consists of an auricle and ventricle, or of two auricles and a ventricle, enclosed in a pericardial chamber. The aerated blood from the gills is returned into the auricle, and driven into the ventricle, from which arise the great systemic vessels. The arteries appear to usually terminate in lacunar blood-spaces between the tissues, but in other cases capillary vessels are stated to intervene between the arteries and veins.

Respiration is variously effected; the members of one great section (*Branchiogastropoda*) being constructed to breathe air dissolved in water, while in another division (*Pulmogastropoda*) the respiration is aerial. In the former division, respiration may be effected in several ways. Firstly, there may be no specialised respiratory organ, the blood being simply exposed to the water in the thin walls of the mantle-cavity (as in some of the *Heteropoda*). Secondly, the respiratory organs may be in the form of outward processes of the integument, exposed in tufts on the back and sides of the animal (as in the *Nudibranchiata*). Thirdly, the respiratory organs may have the form of pectinated or plume-like branchiæ, contained in a more or less complete branchial chamber formed by an inflection of the mantle (fig. 272, *bc*). In many members of this last section the water obtains access to the gills by means of a tubular prolongation or folding of the mantle, forming a "siphon" (fig. 268, *s*),

the effete water being expelled by another posterior siphon similarly constructed.

The number of gill-plumes differs in different groups. In most cases there is only a single branchial plume, placed on the right side of the neck; in other cases an additional gill is present on the left side; and in other forms, again (*e.g.*, *Patella*), the gills are multiple and are arranged in a circle. Lastly, in the Pulmonate Gastropods the breathing-organ is a pulmonary chamber, formed by an inflection of the mantle, the walls of which are richly supplied with blood, while air is admitted to its interior by a distinct aperture. A transition between the Branchiate and Pulmonate groups is effected by forms like *Ampullaria*, in which gills are present, but the walls of the mantle-cavity are in parts highly vascular, and are thus adapted for aerial respiration.

The kidney of the Gastropods corresponds with the "organ of Bojanus" of the Bivalves, but is usually single (a pair of kidneys exist in *Patella*). It is a lamellar or spongy sac, placed near the heart, and opening internally into the pericardium; the external opening of its duct being placed in the mantle-cavity in the neighbourhood of the anus.

The nervous system of the typical Gastropods consists of three principal pairs of ganglia so arranged as to form a double circum-œsophageal ring. The cerebral ganglia are connected by a commissure above the gullet, and give off two lateral commissures on each side. One of these commissures goes to the pedal ganglion on each side; the other goes to a second laterally-placed ganglion, which belongs to the group of the "visceral" or "parietosplanchnic" ganglia, and which is termed the "pleural" ganglion. The two pleural ganglia are connected by commissures with the pedal ganglia, and are also connected with one another by a long posteriorly directed "visceral" commissure, upon which ganglia are commonly developed. As regards sense-organs, there are usually two eyes, which are commonly situated at the summit or base of a pair of cephalic tentacles. Two auditory sacs (otocysts) are usually present, and are placed close to the pedal ganglia. The cephalic tentacles are the principal organs of touch. Lastly, there exists on the front of the visceral sac a peculiar ciliated single or double organ ("Spengel's organ"), which is believed to have an olfactory function.

The typical Gastropods (*Prosobranchiata*) have the sexes in different individuals; but the Opisthobranchiate and Pulmonate forms are monœcious. In these latter, the ovary and testis are usually combined to form a common generative gland

("hermaphrodite gland"). In addition to the oviduct (which is often dilated into a "uterus") and the vagina, there are usually appended to the female organs an "albumen gland" and a "receptaculum seminis." The male organs consist in general of a testis, vas deferens, vesicula seminalis, and a distinct penis.

A few Gastropods retain the eggs within the uterus until they are hatched; but the majority are oviparous. The eggs are often laid in the form of a string or band ("nidamental ribbon"); or they may be enclosed in horny capsules (as, for example, in the common Whelk, fig. 269, C). The young, when first hatched, are provided with an embryonic shell, which in the adult may become concealed in a fold in the mantle, or may be entirely lost. In the common spiral Univalves the embryonic shell remains at the summit of the spire as the "nucleus" of the adult shell. In the branchiate Gastropods the embryo (fig. 261) is protected by a small nautiloid shell, and passes through a "veliger" stage, swimming freely by means of a ciliated, often lobed "velum." Among the Pulmonate Gastropods, those which are strictly terrestrial pass through no metamorphosis, the "velum" being absent in the embryo.

CHAPTER XLI.

DIVISIONS OF THE GASTROPODA.

THE *Gastropoda* are divided into two primary sections or subclasses, according as the respiratory organs are adapted for breathing air directly or dissolved in water: termed respectively the *Pulmonata*, *Pulmonifera*, or *Pulmogastropoda*, and the *Branchiata*, *Branchifera*, or *Branchiogastropoda*.

SUB-CLASS A. BRANCHIATA OR BRANCHIOGASTROPODA.—In this sub-class *respiration is aquatic*, effected by the thin walls of the mantle-cavity, by external branchial tufts, or by pectinated or plume-like gills contained in a more or less complete branchial chamber.

This sub-class comprises three orders—viz., the *Prosobranchiata*, the *Opisthobranchiata*, and the *Heteropoda*.

ORDER I. PROSOBRANCHIATA.—The members of this order are Gastropods in which the gills are situated in front of the heart, and the auricle is placed in front of the ventricle. The

gills are typically plume-like, and are lodged in a branchial chamber formed by a fold of the mantle. The foot is large and adapted for creeping, and the sexes are distinct.

The order *Prosobranchiata* includes the most characteristic members of the Branchiate Gastropods, and is divisible into two principal sections, termed respectively *Siphonostomata* and *Holostomata*, according as the aperture of the shell is notched or produced into a canal, or is simply rounded and "entire."

The *Siphonostomata*, of which the common Whelk (*Buccinum undatum*, fig. 269) may be taken as an example, are all marine, and are mostly carnivorous in their habits. The mouth of the shell is notched in front, or is produced into a canal, for the lodgment of a "siphon" or fold of the mantle, by which water is introduced into the branchial chamber (fig. 274).

Fig. 273.—*Scalaria Grœnlandica*, a Holostomatous Univalve.

Fig. 274. — *Oliva porphyria*, a Siphonostomatous Univalve.

Fig. 275. — *Cerithium aluco*, a Univalve of the section *Holostomata*, but with the shell-mouth channelled.

The following families are comprised in this section: *Strombidæ* (Wing-shells), *Muricidæ*, *Buccinidæ* (Whelks), *Conidæ* (Cones), *Volutidæ*, and *Cypræidæ* (Cowries).

The *Holostomata*, of which the common Periwinkle (*Littorina littorea*) is a good example, are either spiral or limpet-shaped, the aperture of the shell being in most cases entire (fig. 273). In some forms (*e.g.*, in *Cerithium*, fig. 275) the aperture of the shell is channelled in front. They are mostly plant-eaters, and they may be either marine or inhabitants of fresh water. The following families are included in this section: *Naticidæ*, *Pyramidellidæ*, *Cerithiadæ*, *Melaniadæ*, *Tur-*

ritellidæ, *Littorinidæ* (Periwinkles), *Paludinidæ* (River-snails), *Neritidæ*, *Turbinidæ* (Top-shells), *Haliotidæ* (Ear-shells), *Fissurellidæ*, (Key-hole Limpets), *Calyptræidæ* (Bonnet Limpets), and *Patellidæ* (Limpets).

ORDER II. OPISTHOBRANCHIATA.—The members of this order are Gastropods in which the branchiæ are situated behind the heart, and the auricle is behind the ventricle of the heart. The gills are not usually contained in a special branchial chamber, and are commonly more or less exposed to view. The shell is wanting or present, being in the latter case often rudimentary. The sexes are united in the same individual.

The *Opisthobranchiata*, or "Sea-slugs," may be divided into two sections, the *Tectibranchiata* and *Nudibranchiata*, according as the branchiæ are protected or are uncovered.

The first section, that of the *Tectibranchiata*, is distinguished by the fact that the animal is usually provided with a shell, both in the larval and adult state, and that the branchiæ are protected by the shell or by the mantle. Under this section are included the families of the *Tornatellidæ*, *Bullidæ* (Bubble-shells), *Aplysiadæ* (Sea-hares), *Pleurobranchidæ*, and *Phyllidiadæ*.

In the second section, that of the *Nudibranchiata* (fig. 276), the animal is destitute of a shell, except in the embryo condition, and the branchiæ (rarely absent, as in *Limapontia* and *Rhodope*) are always placed externally on the back or sides of the body. This section comprises the families *Doridæ* (Sea-lemons), *Tritoniadæ*, *Æolidæ*, *Phyllirhoidæ*, and *Elysiadæ*. Specimens of the Sea-slugs and Sea-lemons may at any time be found creeping about on sea-weeds, or attached to the under surface of stones at low water. The head is furnished with tentacles, which appear to be rather connected with the sense of smell than to be used as tactile organs; and behind the tentacles are generally two eyes. Locomotion is effected, as in the true Slugs, by creeping about on the flattened foot.

Fig. 276.—Nudibranchiata. *Doris Johnstoni*, one of the Sea-lemons.

ORDER III. HETEROPODA (NUCLEOBRANCHIATA).—The members of this group are pelagic, free-swimming Gastropods, in which the foot is converted into a vertically-flattened fin-like organ. The head is large, and bears a pair of highly-developed and movable eyes. The sexes are distinct.

The *Heteropoda* are pelagic in their habits, and are found swimming at the surface of the sea. They are to be regarded

as the most highly organised of all the *Gastropoda*, at the same time that they are not the most typical members of the class. Some of them can retire completely within their shells, closing them with an operculum ; but most have large bodies, and the shell is either small (fig. 277) or entirely wanting.

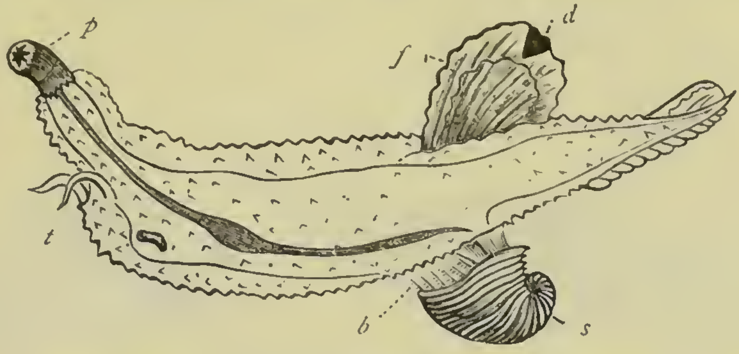

Fig. 277.—Heteropoda. *Carinaria cymbium*. *p* Proboscis; *t* Tentacles; *b* Branchiæ; *s* Shell; *f* Foot; *d* Disc. (After Woodward.)

They swim by means of a flattened ventral fin, or by an elongated tail, and adhere at pleasure to sea-weed by a small sucker situated on the side of the fin. These organs are merely modifications of the foot of the ordinary Gastropods ; the fin-like tail being the "metapodium" (as shown by its occasionally carrying an operculum), the sucker being the "mesopodium," and the ventral fin being a modified "propodium." The "epipodia" are apparently altogether wanting. Respiration is sometimes carried on by distinct branchiæ, but in many cases these are wanting, and the function is performed simply by the walls of the pallial chamber.

The *Heteropoda* are divided into the two families *Firolidæ* and *Atlantidæ*, the former characterised by having a small shell covering the circulatory and respiratory organs, or by having no shell at all; whilst in the latter there is a well-developed shell, into which the animal can retire, and an operculum is often present.

Sub-class B. Pulmonata or Pulmogastropoda.—In this sub-class of the *Gastropoda respiration is aerial*, and is carried on by an inflection of the mantle, forming a pulmonary chamber into which air is admitted by an external aperture. The sexes are united in the same individual.

The *Pulmonata* include the ordinary Land-snails, Slugs, Pond-snails, &c., and are usually provided with a well-developed shell, though this may be rudimentary (as in the Slugs). Though formed to breathe air directly, many of the

members of this sub-class are capable of inhabiting fresh water. The common Pond-snails are good examples of these last. The condition of the shell varies greatly. Some, such as the common Land-snails, have a well-developed shell, within which the animal can withdraw itself completely. Others, such as the common Slugs (fig. 278), have a rudimentary shell, which is completely concealed within the mantle.

The head is well developed, and carries two or four ten-

Fig. 278.—*Limax Sowerbyi*, one of the Slugs. (After Woodward.

tacles. The eyes are sometimes situated at the base of the tentacles, as in the Pond-snails. In the Land-snails, on the other hand, in which there are four tentacles, the hinder pair of feelers are long and retractile, and carry the eyes at their tips. The mouth usually carries superiorly an unpaired horny jaw ; and a radula is present. The opening of the pulmonary chamber is placed on the right side of the neck (under cover of the shell in the Land-snails), and the openings of the anus and kidney are close beside it. The generative apertures are also placed on the right side of the neck, but further forward.

In most of the Pulmonates (*Inoperculata*) the foot does not produce an operculum, but many of such forms close the mouth of the shell during periods of torpidity with a temporary curtain ("epiphragm") of hardened mucus, in which a little lime is sometimes deposited. The Inoperculate Pulmonates comprise the families of the *Helicidæ* (Land-snails), *Limacidæ* (Slugs), *Oncidiadæ*, *Limnæidæ* (Pond-snails), and *Auriculidæ*.

On the other hand, in the two families of the *Cyclostomidæ* and *Aciculidæ*—hence called *Operculata* — the foot produces a horny operculum. The *Cyclostomidæ* are, however, often regarded as being really referable to the Holostomatous section of the Prosobranchiate Gastropods.

Distribution of the Gastropoda in Space.—As a class, the *Gastropoda* have a world-wide range, some forms being exclusively marine, others inhabiting fresh waters, while others,

again, live upon the land. Amongst the *Prosobranchiates*, the entire order of the *Siphonostomata*, and the majority of the *Holostomata*, are marine; but, amongst the latter, the *Melaniadæ* and *Paludinidæ* are confined to fresh waters, and the *Cerithiadæ* and *Neritidæ* include a number of fresh or brackish water forms. The *Opisthobranchiates* are exclusively marine, mostly littoral in their habits, but occasionally oceanic. The *Heteropoda* are exclusively marine and pelagic. Lastly, amongst the *Pulmonates* many forms (such as the Snails and Slugs) are strictly terrestrial, whilst others (*Limnæa*, *Planorbis*, *Ancylus*, &c.) are found in fresh or brackish waters.

Distribution of the Gastropoda in Time.—The *Gastropoda* are represented in past time from the Upper Cambrian rocks up to the present day. Of the *Branchiata* the *Holostomata* are the characteristic Gastropods of the Palæozoic period, the *Siphonostomata* not being certainly represented in rocks earlier than the Trias, and not attaining their maximum till the present day. The place of the carnivorous *Siphonostomata* in the Palæozoic seas appears to have been filled by the Tetrabranchiate Cephalopods. The Branchiate Gastropods of fresh water are chiefly represented as fossils by the genera *Melania*, *Paludina*, *Valvata*, and *Ampullaria*.

The *Heteropoda* are of very ancient origin, having commenced their existence in the lowest Ordovician deposits. The genera *Bellerophon*, *Cyrtolites*, and *Maclurea* are exclusively Palæozoic; *Bellerophina* is found in the Gault (Secondary), and *Carinaria* has been detected in the Tertiaries.

The Pulmonate *Gastropoda*, as was to be anticipated, are not found abundantly as fossils, occurring chiefly in lacustrine and estuarine deposits, in which the genera *Limnæa*, *Physa*, *Ancylus*, &c., are amongst those most commonly represented. These, however, are entirely Mesozoic and Kainozoic. In the Palæozoic period the sole known representatives of the *Pulmonata* are certain species of *Pupa*, *Dawsonella*, and *Zonites*, which have been detected in the Carboniferous rocks.

Polyplacophora.

The little group of the Chitons may be here considered briefly as a special division of Molluscs, to which the name of *Polyplacophora* may be given. The *Chitons* have generally been regarded as an aberrant group of the Gastropods, but they differ from the latter in the fact that *the body is laterally*

symmetrical, no distinct head is present, there are no differentiated cerebral ganglia, and the shell is composed of eight calcareous plates arranged in a longitudinal series along the dorsal surface.

The Chitons have an elongated, worm-like, bilaterally symmetrical body, with the mouth at the anterior end, surrounded by a circlet of tentacles (fig. 279, *t*), and the anus at the hinder end of the body. The upper surface of the mantle secretes a "multivalve" shell (fig. 279, B), composed of eight transverse imbricated plates, which succeed one another from before backwards, and are embedded in the leathery or fibrous border of the mantle, which may be plain, or may be beset with bristles, spines, or scales. The foot forms a creeping disc, and the gills are numerous, (fig. 279, *g*), and are contained in an imperfect pallial chamber or groove between the margins of the foot and the edge of the mantle.

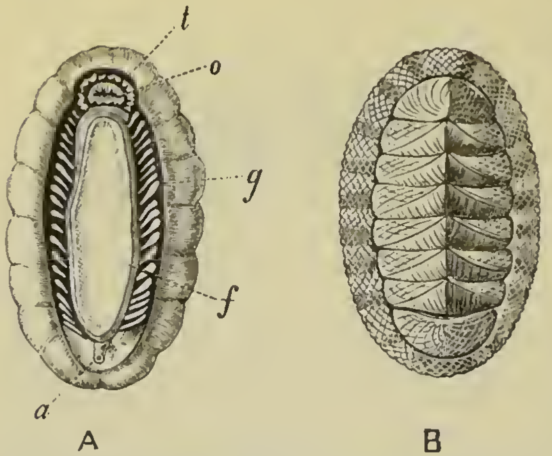

Fig. 279.—A, Under surface of a species of *Chiton* (after Cuvier): *t* Fringe of tentacles round the mouth (*o*); *g* Branchiæ; *f* Under surface of foot; *a* Anus. B, Shell of *Chiton squamosus*, reduced one-half. (After S. P. Woodward.)

There is no distinct head, nor are tentacles developed. The nervous system consists of an œsophageal ring which gives off branches backwards, but the cerebral, pedal, and parieto-splanchnic ganglia are not developed; though a pair of small sub-pharyngeal ganglia ("buccal ganglia") are present. The "radula" is present, and the kidneys and generative ducts are paired.

The Chitons are all inhabitants of the sea, and have an especial zoological interest as forming a connecting-link between the Molluscs and the Worms. They present, in particular, points of relationship with the genus *Chætoderma*, which has usually been included among the Gephyrean Worms. Geologically speaking, the *Chitonidæ* are a very ancient group, representatives of the family appearing as early as the Devonian period.

Scaphopoda.

The little group of the Tooth-shells (*Dentaliidæ*) may also be shortly considered here, as a special division of Molluscs (*Scaphopoda*) in some respects intermediate between the Lamellibranchs and the Gastropods, with points of relationship to the Pteropods. The animal in *Dentalium* (fig. 280) is bilaterally symmetrical, and is enclosed in a continuous mantle, which secretes a tubular shell, which is open at both ends. From the large anterior aperture of the shell is protruded the foot, and a circle of tentacles surrounding the mouth, but there is no distinct head. The oral tentacles appear to discharge a respiratory function, but there are no specialised branchiæ, nor is a definite heart present. The nervous system is of the Molluscan type; the kidneys are paired; the sexes are distinct; and the pharynx is furnished with a radula.

Fig. 280.—*Dentalium vulgare*, of the natural size, with the oral tentacles protruded from the anterior opening of the shell (after Lacaze-Duthiers). In its natural position the anterior extremity of the animal is buried obliquely in the sand, and the small pointed end projects upwards into the water.

Dentalium and its allies (*Siphonodentalium* and *Entalium*) are exclusively marine, and are found burrowing in the sand in shallow water. The antiquity of the *Scaphopoda* as a zoological group is very high, the earliest known species of *Dentalium* appearing in the Devonian rocks.

CHAPTER XLII.

PTEROPODA.

Class III. Pteropoda. — The Pteropods are *free and pelagic Molluscs, without a definite head, and having the lateral portions of the foot* ("*epipodia*") *developed into a pair of wing-like fins. The sexes are united in the same individual.*

The "Winged Snails" or Pteropods are of small size, and are found swimming near the surface of the open ocean, often in vast numbers. They are related on the one hand to the *Gastropoda*, and on the other hand to the *Cephalopoda*. There is no distinctly differentiated head, and the mouth is placed anteriorly in the centre of the fore-part of the foot. The lateral parts of the foot ("epipodia") are developed into a pair of wing-like fins (fig. 281, *e*), by means of which the

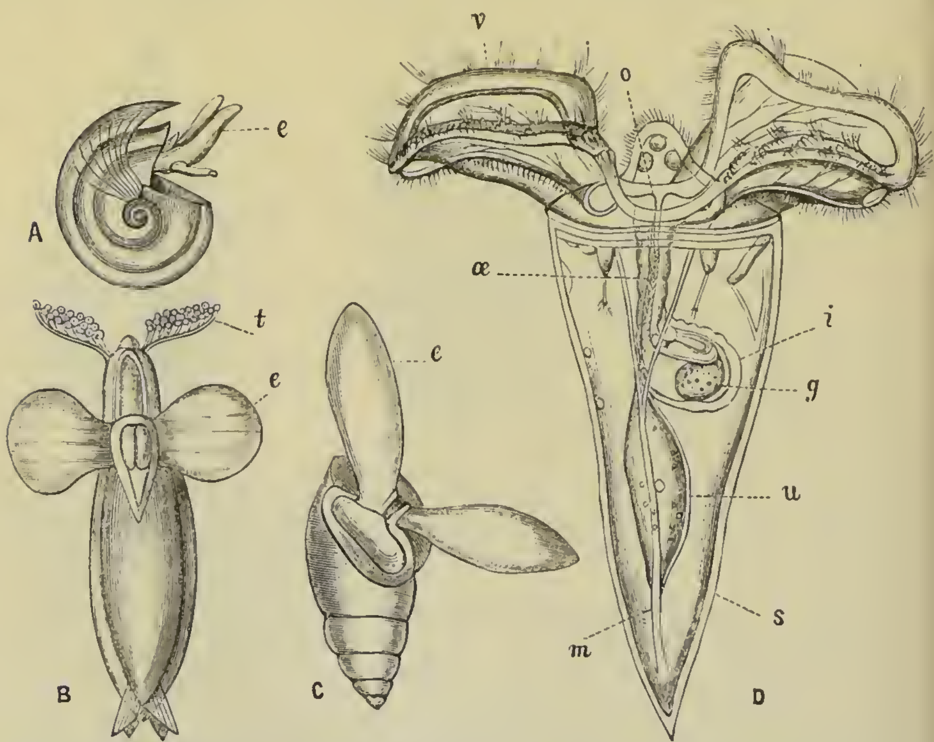

Fig. 281.—Pteropoda. A, *Spirialis rostralis*. B, *Pneumodermon violaceum*. C, *Heterofusus buliminoides*. All enlarged. *e* Epipodia or fins; *t* Tentacles. D, Larva of *Cleodora lanceolata*, greatly enlarged (after Fol): *v* Velum; *o* Mouth; *œ* Gullet; *g* Stomach; *i* Intestine; *m* Columellar muscle; *s* Shell; *u* Yolk-sac.

animal swims actively, and which correspond morphologically with the "funnel" of the Cephalopods. The hind part of the foot ("metapodium") is rudimentary, but in some cases develops an operculum (*Limacinidæ*). The anterior extremity of the body also may be furnished with tentacular processes, which in some cases are provided with suckers (*e.g.*, in *Pneumodermon*, fig. 281, B).

The mantle is sometimes rudimentary in the adult (*Gymnosomata*), in which case the body is naked, and is not protected by a shell. In other forms (*Thecosomata*) the mantle is well

developed and secretes a shell, which is usually symmetrical in form, calcareous or chitinous in composition, and very delicate in texture. The shell most commonly consists of a dorsal and ventral plate united (figs. 282, 283), or it may be

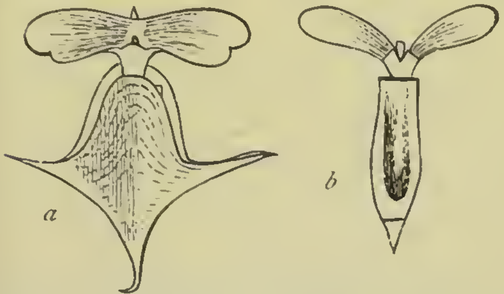

Fig. 282.—Pteropoda. *a Cleodora pyramidata; b Cuvieria columnella.* (After Woodward.)

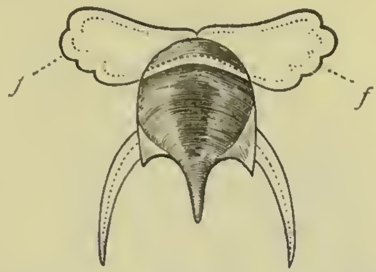

Fig. 283.—*Hyalea tridentata*, showing the shell and the lateral fins attached to the sides of the head (*f f*).

rolled into a spiral (fig. 281, A and C), which may be flat or oblique.

The pharynx in the Pteropods is furnished with a radula, and the termination of the alimentary canal is usually placed anteriorly and on the right side of the body. The heart consists of an auricle and ventricle, and the circulation is lacunar. The respiratory organs are rudimentary, not consisting of distinct branchiæ, but sometimes represented by ciliated folds of the mantle placed within a branchial cavity. The kidney is like that of the majority of the Gastropods in being unpaired, and it communicates internally with the pericardial sac, and externally with the pallial chamber, or with the exterior surface of the body. The nervous system is of the same general type as that of the Gastropods, and there is a pair of otocysts; but the eyes are rudimentary or absent.

The Pteropods are all hermaphrodite, and the young pass through a metamorphosis, having at first a ciliated "velum" attached to the sides of the head (fig. 281, D).

The *Pteropoda* are divided into two orders, termed *Thecosomata* and *Gymnosomata;* the former characterised by possessing an external shell and an indistinct head; the latter by being devoid of a shell, and by having a distinct head, with fins attached to the neck.

The *Pteropoda*, as already said, are found swimming near the surface in the open ocean, and they are found in all seas from the tropics to within the arctic circle, sometimes in such numbers as to discolour the water for many miles. They are nocturnal in their habits, and, minute as they are, they con-

stitute in high latitudes one of the staple articles of diet of the whale. They themselves are, in turn, carnivorous, feeding upon small Crustaceans and other diminutive animals. Though all the living forms are small, geology leads us to believe that there formerly existed comparatively gigantic representatives of this class of the *Mollusca*.

DISTRIBUTION OF PTEROPODA IN TIME.—The Pteropods are not largely represented in fossiliferous deposits, but they have a wide range in time, extending from the Upper Cambrian rocks up to the present day. The *Hyolithes* (*Theca*) and *Conularia* of the Palæozoic period, if truly Pteropods, are of comparatively gigantic size. Both commence their existence in the Ordovician or Upper Cambrian, and the former is entirely Palæozoic. The genus *Conularia*, however, extends into the Mesozoic period, and is found in the Liassic rocks. The Silurian fossils which form the genus *Tentaculites*, though often referred to the Tubicolar Annelides, appear to belong without doubt to the *Pteropoda*. The recent genus *Styliola* is stated to occur in the Silurian rocks. Hardly any forms of the *Pteropoda* have been certainly recognised as occurring in the Secondary rocks, but various recent genera, such as *Hyalea* (fig. 283), *Cleodora*, and *Cuvieria*, are represented in the Tertiary period.

CHAPTER XLIII.

CEPHALOPODA.

CLASS IV. CEPHALOPODA.—The members of this class are *bilaterally symmetrical Molluscs, with a large head, and having the body enclosed in a muscular mantle. The fore-part of the foot is split up into eight or more muscular processes or "arms" which surround the mouth; while the epipodia are well developed, and give rise, by apposition or fusion, to a muscular tube ("funnel") through which the effete water of respiration is expelled. One or two pairs of gills are contained within the pallial sac, and the sexes are always distinct.*

The *Cephalopoda*, comprising the Cuttle-fishes, Pearly Nautilus, &c., constitute the most highly organised of the classes of the *Mollusca*. They are all marine and carnivorous, and are possessed of considerable locomotive powers. At the bottom of the sea they can walk about, head downwards, by

means of the arms which surround the mouth, and which are usually provided with numerous suckers or "acetabula." They are also enabled to swim, partly by means of lateral expansions of the integument or fins (not always present), and partly by means of the forcible expulsion of water through the tubular "funnel," the reaction of which causes the animal to move in the opposite direction.

The majority of the living Cephalopods are naked, possessing only an internal skeleton, and this often a rudimentary one; but the female Argonaut (Paper Nautilus), and the Pearly Nautilus, are protected with an external shell, though the nature of this is extremely different in the two forms.

The integument in all the Cephalopods except the Pearly Nautilus is furnished with a layer of peculiar cells known as "chromatophores." These are large-sized cells, filled with brightly-coloured pigment-granules, and having attached to their walls minute radiating bundles of muscular fibres. By the contraction of these the chromatophore is dilated, while on relaxation of these the cell resumes its original form in virtue of its own elasticity. By this peculiar mechanism the Cuttle-fishes can adapt their colours to their surroundings, and can rapidly change their tints.

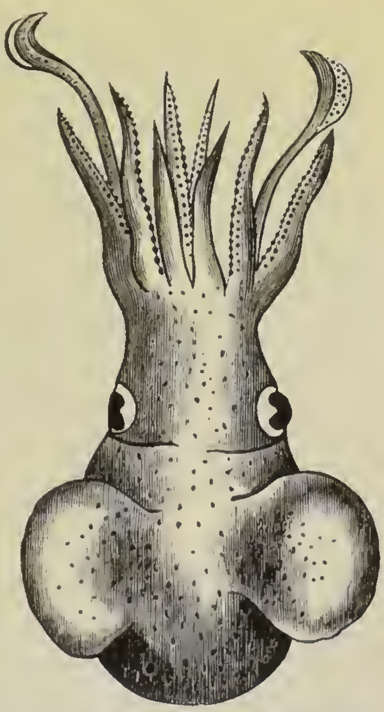

Fig. 284.—Cephalopoda. *Sepiola Atlantica*, one of the Cuttle-fishes. (After Woodward.)

The body in the *Cephalopoda* is bilaterally symmetrical, and the cephalic region (*prosoma*) is conspicuously marked out, and is separated from the visceral region (*metasoma*), which is enclosed in the mantle. The mantle-cavity is situated on the under side of the body, when the animal is placed in its natural position. The head is very distinct, bearing a pair of large globular eyes, and having the mouth in its centre. The mouth is surrounded by a circle of eight, ten, or more, long muscular processes, or "arms" (fig. 284), which are generally provided with rows of stalked or sessile suckers. Each sucker, or "acetabulum," consists of a cup-shaped cavity, the muscular fibres of which con-

verge to the centre, where there is a little muscular eminence or papilla. When the sucker is applied to any surface, the contraction of the radiating muscular fibres depresses the papilla so as to produce a vacuum below it, and in this way each sucker acts most efficiently as an adhesive organ. In some forms (*Decapoda*) the base of the papilla, or piston, is surrounded by a horny dentated ring, and in some others (as in *Onychoteuthis*) the papillæ are produced into long claws. In the Octopod Cuttle-fishes there are only eight arms, and these are all nearly alike. In the Decapod Cuttle-fishes there are ten arms, but two of these —called "tentacles"—are much longer than the others, and bear suckers only at their extremities, which are enlarged and club-shaped. In the Pearly Nautilus the arms are numerous and are devoid of suckers, but it is not clear that these are really homologous with the "arms" of the Cuttle-fishes.

In all the Cuttle-fishes, the mouth is placed in the centre of the "foot," and it is by a splitting up of the margins of the foot into long muscular processes that the "arms" are produced. The arms are always symmetrically arranged in a dorsal, a ventral, and two lateral pairs; and the "tentacles" (when present) are placed on the ventral surface, between the 3d and 4th pairs of arms. The tentacles may or may not be retractile into pouches placed below the eyes, and their length may be many times greater than that of the body. They are organs of prehension; and the arms are in addition employed by the animal in locomotion, enabling it to creep along the sea-bottom head downward.

In all the Decapod, and in some of the Octopod forms, the sides of the body are produced into muscular expansions or fins (figs. 284 and 291), with which the animal swims head foremost. In all the Cephalopods, also, the lateral margins of the foot ("epipodia") are either placed in apposition (*Nautilus*) or are actually united (Cuttle-fishes), in such a manner as to form a muscular tube, known as the "funnel." The funnel (fig. 285, *f*) is placed on the lower surface of the body, with its anterior extremity projecting beyond the mantle, while it opens behind into the pallial chamber. It serves for the elimination of the water which has been used in respiration, and the out-going currents also carry away with them the excretions of the kidneys and of the ink-sac, together with the fæces. By the contractions of the mantle, the water contained in the pallial sac can also be driven through the funnel in a succession of jets, driving the animal backwards through the water.

The mouth leads into a muscular buccal cavity or pharynx (fig. 285, *ph*), containing two powerful mandibles, working vertically, resembling the beak of a parrot in shape, and either horny (as in the Cuttle-fishes), or partially calcareous in composition (as in *Nautilus*). The buccal cavity contains a toothed tongue or "radula," and conducts by a gullet, into which salivary glands pour their secretion, to a capacious stomach (fig. 285, *s*), to which a capacious cæcum is usually appended. The intestine (fig. 285, *in*) is short, and the anal opening is placed at the base of the funnel. A large and well-developed liver (*l*) is present. In the Cuttle-fishes there is also a special glandular organ, the "ink-bag" (fig. 285, *i*), which secretes an inky fluid, which the animal can discharge into the water, so as to facilitate its escape when menaced or pursued. The duct of the ink-bag opens, along with the intestine, at the base of the funnel; but this apparatus is entirely wanting in the Tetrabranchiate Cephalopods.

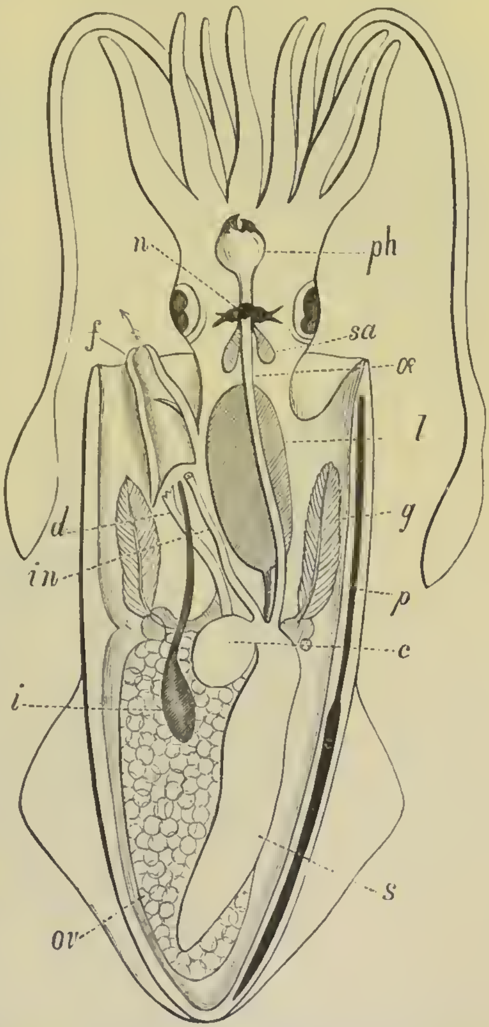

Fig. 285.—Diagram of the structure of a Cuttle-fish. *ph* Pharynx, with the horny mandibles; *sa* Salivary glands; *œ* Œsophagus; *s* Stomach; *c* Gastric cæcum; *in* Intestine; *l* Liver; *n* Œsophageal nerve-collar; *g* One of the gills, with the branchial heart at its base; *i* Ink-bag, its duct opening along with the intestine and generative duct at the base of the funnel; *ov* Ovary; *d* Oviduct (the nidamental and accessory glands are omitted); *f* Funnel; *p* Pen, lying in the mantle dorsally.

The kidneys (fig. 286, *r r*) are paired, and have the form of spongy sacs developed upon the venæ cavæ, and communicating with the pericardial sac. The circulatory organs consist of a central ventricle, into which the aerated blood from the gills is poured by two laterally-placed auricles (fig. 286,

d d), developed upon the branchial veins where they leave the branchiæ. In *Nautilus*, in which there are four gills, there are four auricles. The blood finds its way from the arteries to the veins mostly through the intervention of a system of capillaries, but also by means of sinuses and lacunæ among the tissues. The two great trunks ("branchial arteries") which carry the venous blood to the gills are further provided, in the Cuttle-fishes, with special contractile dilatations, situated one at the base of each branchia, and known as the "branchial hearts" (fig. 286, *e e*). These structures are wanting in *Nautilus*.

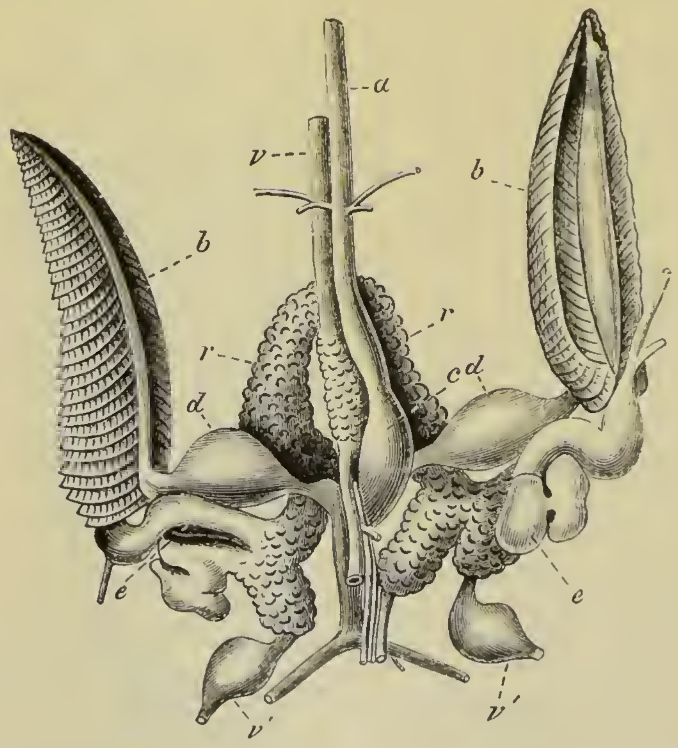

Fig. 286.—Central organs of the circulation, gills, and renal organs of *Sepia officinalis*. (After John Hunter). *a* Aorta; *v* Vena cava; *v′ v′* Visceral veins; *c* Ventricle; *d d* Right and left auricles; *e e* Branchial hearts; *b b* Branchiæ; *r r* Renal organs.

The respiratory organs are in the form of two (Cuttle-fishes) or four (*Nautilus*) plume-like gills, placed symmetrically on the sides of the body within the pallial sac. The gills (fig. 286, *b b*) consist each of a central stem, bearing finely-divided lateral vascular laminæ; and as they are not ciliated, the necessary respiratory currents are maintained by the alternate contractions and expansions of the muscular walls of the mantle-sac. In each expansion the water finds its way into the pallial

chamber by the opening between the rim of the mantle and the neck; and in each contraction it is expelled through the tube of the funnel, which is so constructed as to allow of the egress but to prevent the ingress of the water.

The central nervous system consists of the three normal pairs of ganglia—the cerebral, pedal, and visceral or parieto-splanchnic—but these are aggregated to form an œsophageal collar (fig. 285, *n*). The organs of sense are a pair of large and very highly-developed eyes, and a pair of auditory sacs. The great œsophageal nerve-collar is protected by a cartilaginous plate, which foreshadows the cranium of the *Vertebrata;* this also sends out prolongations which strengthen and defend the eye, and the auditory chambers are excavated in its substance.

The sexes in all the *Cephalopoda* are in different individuals,

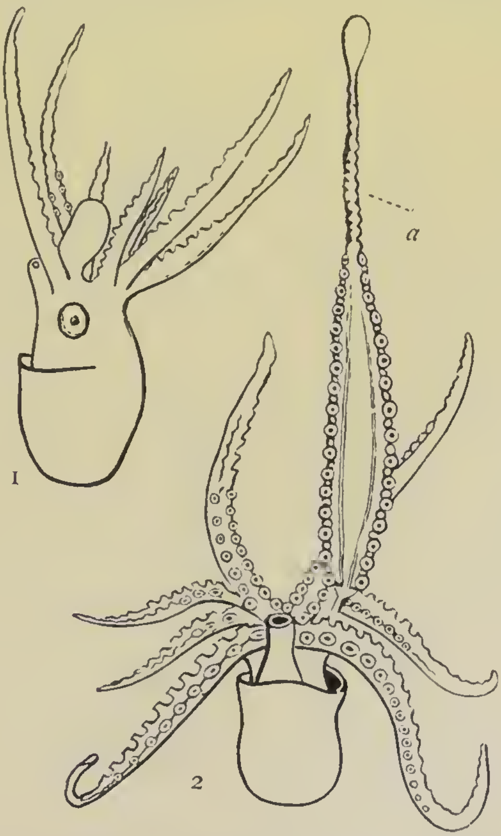

Fig. 287.—1. *Octopus carena* (male), showing cyst in place of the third arm. 2. Ventral side of an individual, more developed, with the hectocotylus (*a*). (After Woodward.)

the males and females generally being more or less unlike externally. In this order the ducts of the generative organs open into the pallial chamber, at the base of the funnel; and

each individual, besides the essential organs of reproduction (testis or ovary), generally possesses accessory glands; those of the female ("nidamental glands") secreting a viscid material which unites the eggs together, whilst those of the male coat the spermatozoa, and aggregate them into peculiar worm-like filaments, from six to eight lines in length, termed "spermatophores," or the "moving filaments of Needham." The spermatophore is filled with spermatozoa, and possesses the power of expanding when moistened, rupturing, and expelling the contained spermatozoa with considerable force. During the congress of the sexes the male transfers the spermatophores to the pallial chamber of the female, true intromission not being possible, but the mode in which this transference is effected differs in different cases, and is not universally known.

In the males of many of the Cuttle-fishes, one of the arms is peculiarly modified, and is said to be "hectocotylised," but the extent to which this modification is carried differs in different cases, and it is not always the same arm in different species which is thus affected. In some cases the "hectocotylised" arm is little altered from its ordinary form, and though the alteration be primarily sexual, the arm is not certainly known to play any part in the reproductive process. In other cases, again, such as *Octopus carena* (fig. 287), *Tremoctopus violaceus* (fig. 288, *b*), and *Argonauta argo* (fig. 288, *a*), the "hectocotylised" arm is the efficient agent in the impregnation of the female. It is, in these forms, longer and thicker than the other arms, and possesses posteriorly a sac which is filled with spermatophores. During the reproductive act the "hectocotylised" arm is actually detached by the male, and deposited, with its freight of spermatophores, within the pallial chamber of the female. When thus detached (fig. 288, *b*), it is capable of independent movement, and when first found in this free condition within the mantle-cavity of the female Argonaut, it was regarded as a parasitic worm. Cuvier gave the name of "Hectocotylus Octopodis" to it, under this belief as to its nature. Hence the name of "hectocotylus" (in allusion to the suckers which it carries) is still applied to the detached arm; whereas the arm, if not detached, is simply said to be "hectocotylised."

In those cases in which the hectocotylised arm is not detached, it is asserted by Steenstrup that it is employed by the male in the direct transference of the spermatophores to the pallial chamber of the female; though it is still uncertain how the spermatophores find their way from the seminal ducts to the sac in the interior of the arm.

The eggs of the Cuttle-fishes are enclosed, singly or many together, in special capsules, which are generally attached in bunches to some foreign body. The ovum undergoes partial

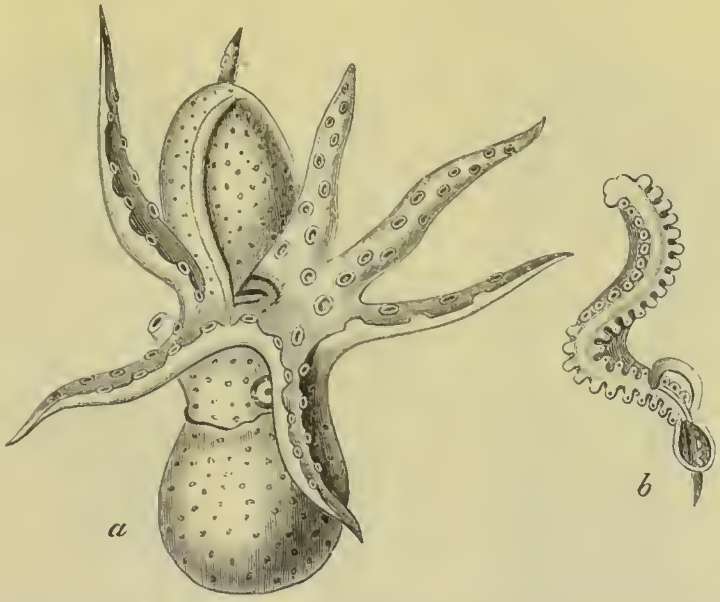

Fig. 288.—*a* Male of *Argonauta argo*, with the hectocotylised arm still contained in its enveloping cyst, four times enlarged (after H. Müller); *b* Hectocotylus of *Tremoctopus violaceus*. (After Kölliker.)

segmentation, as in Birds and Reptiles, and the unsegmented portion of the yolk is gradually absorbed by the growing embryo.

The *shell* of the *Cephalopoda* is sometimes external, sometimes internal. The internal skeleton (fig. 289) is known as "the cuttle-bone," "sepiostaire," or "pen" (*gladius*), and may be either corneous or calcareous. In some cases it is rendered complex by the addition of a chambered portion or "phragmacone," which is to be regarded as a visceral skeleton or "splanchnoskeleton." In *Spirula* (fig. 289, *c*) the phragmacone is the sole internal skeleton, and is coiled into a spiral, the coils of which lie in one plane, and are near one another, but not in contact. It thus resembles the shell of the Pearly Nautilus, but it is *internal*, and differs, therefore, in this respect from the *external* shell of the latter, though resembling it in the fact that the last chamber lodges part of the viscera. The only living Cephalopods which are provided with an external shell are the Paper Nautilus (*Argonauta*) and the Pearly Nautilus (*Nautilus pompilius*); but not only is the structure

of the animal different in each of these, but the nature of the shell itself is entirely different. The shell of the Argonaut (fig. 290) is involuted, but is not divided into chambers, and it is secreted by the webbed extremities of two of the dorsal

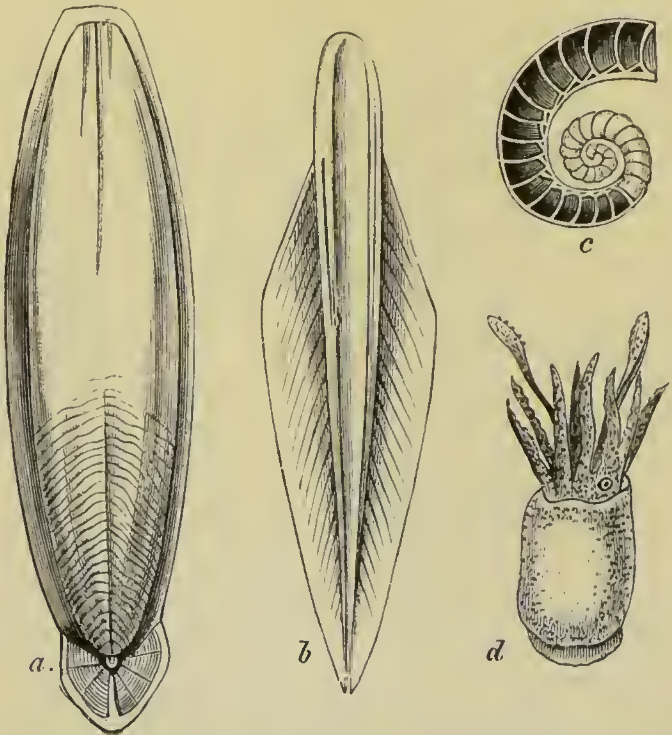

Fig. 289.—*a* Internal Skeleton of *Sepia ornata*; *b* Pen of *Histioteuthis Bonelliana*; *c* Shell ("phragmacone") of *Spirula fragilis*; *d* Animal of *Spirula Peronii*.

arms of the female. The arms are bent backwards, so as to allow the animal to live in the shell, but there is in reality no organic connection between the shell and the body of the animal. In fact, the shell of the Argonaut, being confined to the female, and serving by its empty apex as a receptacle for the ova, may be looked upon as a "nidamental shell," or, as it is secreted by a modified portion of the foot, it may more properly be regarded as a "pedal shell." The shell of the Pearly Nautilus (fig. 295), on the other hand, is a true pallial shell, and is secreted by the body of the animal, to which it is organically connected. It is involuted, but it differs from the shell of the Argonaut in being divided into a series of chambers by shelly partitions or septa, which are pierced by a tube or "siphuncle," the animal itself living in the last chamber only of the shell.

CHAPTER XLIV.

DIVISIONS OF THE CEPHALOPODA.

THE *Cephalopoda* are divided into two extremely distinct and well-marked orders, termed the *Dibranchiata* and *Tetrabranchiata*. The former comprises all the true Cuttle-fishes; whilst the latter, though abundantly represented in past time, has no other living representative than the Pearly Nautilus alone.

ORDER I. DIBRANCHIATA.—The members of this order of the *Cephalopoda* are characterised as being *swimming animals, almost invariably naked, with never more than eight or ten arms, which are always provided with suckers. There are two branchiæ, which are furnished with branchial hearts; an ink-sac is always present; the funnel is a complete tube, and the shell is internal, or, if external, is not chambered.*

The Cuttle-fishes are rapacious and active animals, swimming freely by means of the jet of water expelled from the funnel. The arms constitute powerful offensive weapons, being excessively tenacious in their hold, and being sometimes provided with a sharp claw in the centre of each sucker. They are mostly nocturnal or crepuscular animals, and they sometimes attain to a great size. They may be divided into two sections, *Octopoda* and *Decapoda*, according as they have simply eight arms, or eight arms and two additional "tentacles."

SECTION A. OCTOPODA.—The Cephalopods comprised in this section are distinguished by the possession of not more than eight arms, which are provided with sessile suckers. The shell is absent or rudimentary; in one instance only (the female Argonaut) external. The body is short and bursiform, and ordinarily without fins.

This section comprises the two families of the *Argonautidæ* and the *Octopodidæ*. In the former of these there is only the single genus *Argonauta* (the Paper Sailor, or the Paper Nautilus), in which the female and male differ greatly from one another. The female Argonaut (fig. 290) is protected by a thin *single-chambered* shell, in form symmetrical and involuted, which is secreted by the webbed extremities of the dorsal arms, but is not attached in any way to the body of the animal. It sits in its shell with the funnel turned towards the keel, and the webbed arms applied to the shell. The male Argonaut is much smaller than the female (less than an inch in length),

and is not protected by any shell. The third left arm of the male (fig. 288) is developed in a cyst, and ultimately becomes a "hectocotylus," and is deposited by the male in the pallial chamber of the female.

In the *Octopodidæ* (or Poulpes) there are eight arms, all similar to one another, and united at the base by a web. There is an internal rudimentary shell, represented by two short styles encysted in the substance of the mantle (Owen). The body is seldom provided with lateral fins. The third right arm of the male is primarily developed in a cyst, and ultimately becomes "hectocotylised."

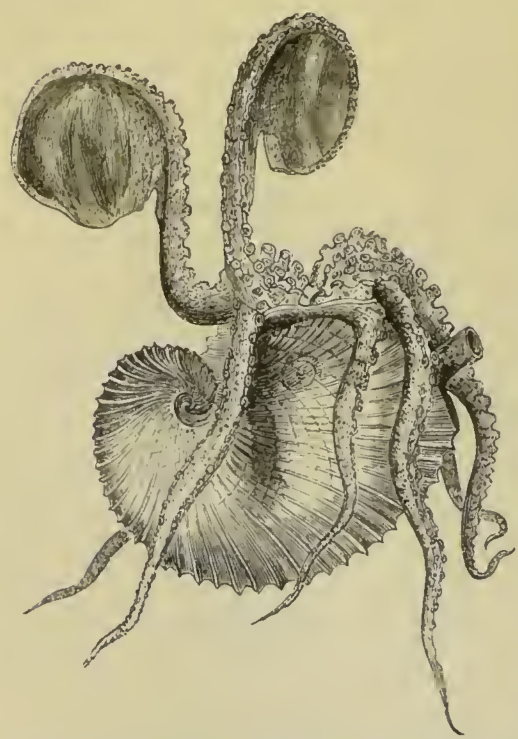

Fig. 290.—*Argonauta argo*, the "Paper Nautilus," female. The animal is represented in its shell, but the webbed dorsal arms are separated from the shell, which they ordinarily embrace.

SECTION B. DECAPODA.—The Cephalopods of this section have eight arms and two additional "tentacles," which are much longer than the true arms, are retractile, and have expanded club-shaped extremities (fig. 291). The suckers are pedunculated; the body is always provided with lateral fins, and the shell is always internal.

This section comprises the three living families of the *Teuthidæ*, *Sepiadæ*, and the *Spirulidæ*, and the extinct family of the *Belemnitidæ*.

The family of the *Teuthidæ* comprises the Calamaries or Squids (fig. 291), characterised by the possession of an elongated body with lateral fins. The shell (fig. 289, *b*) is internal and horny, consisting of a median shaft and of two lateral wings; it is termed the "gladius" or "pen," and in old specimens several may be found lodged in the mantle, one behind the other. In the common Calamary (*Loligo*) the fourth left arm of the male is metamorphosed towards its extremity to subserve reproduction.

In the family of the *Sepiadæ* the internal shell (fig. 289, *a*) is

calcareous ("cuttle-bone" or "sepiostaire"), and is in the form of a broad plate, having an imperfectly-chambered apex. The broad laminated plate is extremely light and spongy, and the chambered apex is called the "mucro." In the living

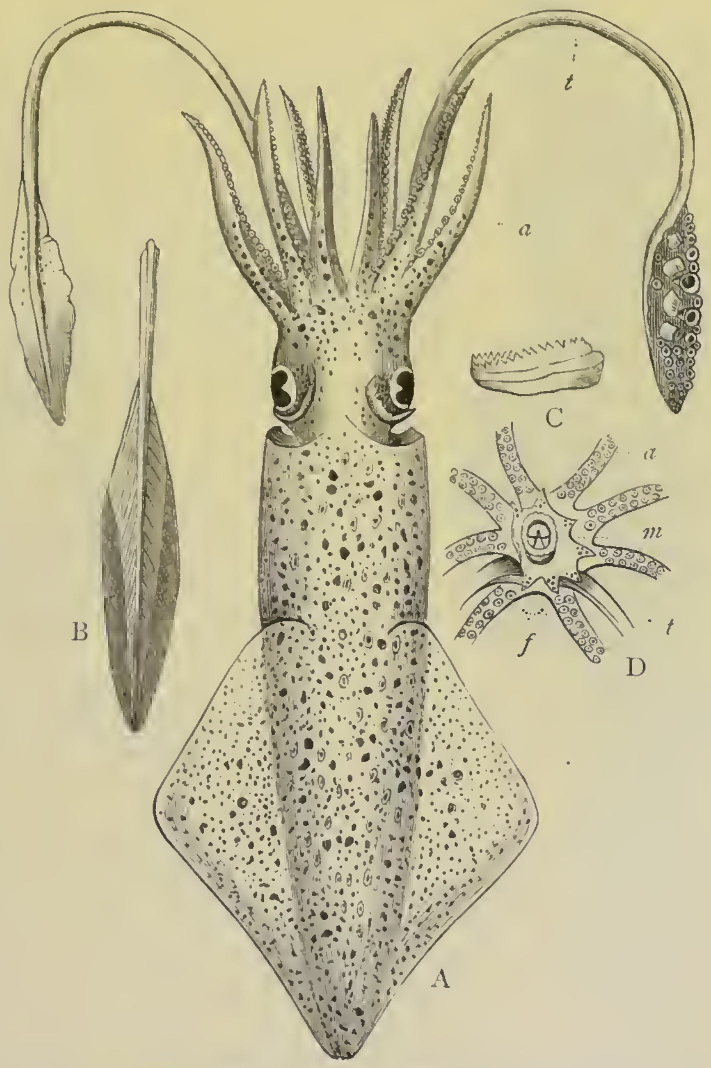

Fig. 291.—A, The Common Calamary (*Loligo vulgaris*), reduced in size: *a* One of the ordinary arms; *t* One of the longer arms or "tentacles." B, Skeleton or "pen" of the same, one-fourth natural size (after Woodward). C, Side view of one of the suckers, showing the horny hooks surrounding the margin. D, View of the head from in front, showing the bases of the arms (*a*) and tentacles (*t*), the mouth (*m*), and the funnel (*f*).

members of the family the body (fig. 292) is provided with long lateral fins, sometimes as long and as wide as the body itself.

In the singular family of the *Spirulidæ* the internal skeleton (fig. 293) is in the form of a nacreous, discoidal shell, the whorls of which are not in contact with one another, and which

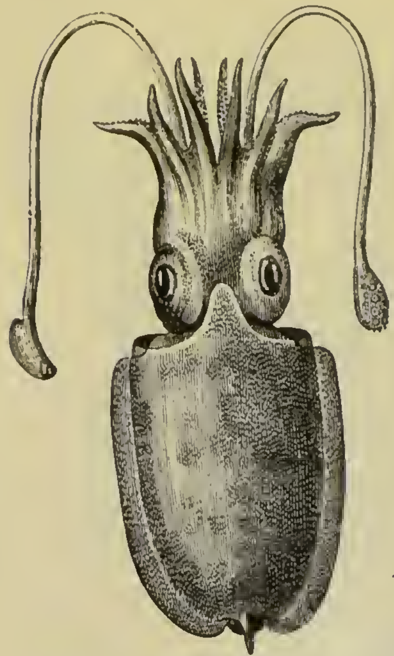

Fig. 292.—*Sepia elegans*, viewed dorsally, and showing the long lateral fins.

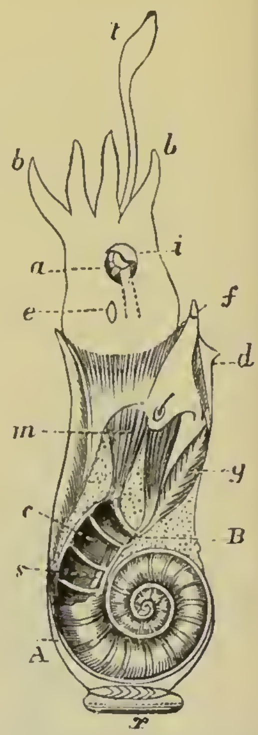

Fig. 293.—Anatomy of *Spirula australis* (after Owen), showing the position of the skeleton.

is divided into a series of chambers by means of partitions or septa which are pierced by a ventral tube or "siphuncle." The body is provided with minute lateral fins, and the arms have six rows of small suckers. The shell of the *Spirula*—commonly known as the "post-horn"—is similar in structure to the shell of the *Nautilus*, but it is lodged in the posterior part of the body of the animal (fig. 293), and is therefore *internal*, whereas the shell of the latter is *external*. It really corresponds to the "phragmacone" of the Belemnite. Though the shell occurs in enormous numbers in certain localities, a single perfect specimen of the animal is all that has been hitherto obtained. In its internal anatomy, *Spirula* is a true Dibranchiate. It has the peculiar feature that the hinder end of the body forms a kind of suctorial disc, apparently employed to moor the animal to foreign bodies. The beaks are not calcified. The retractor muscles of the funnel (*m*) spring from the inner

surface of the last chamber of the shell (as in *Nautilus*); and this chamber also lodges the hinder termination of the liver (Owen).

In the extinct family of the *Belemnitidæ*, our knowledge is chiefly confined to the hard parts. Certain specimens, however, have been discovered, which show that the *Belemnite* had essentially the structure of a Cuttle-fish, such as the recent Calamary. The body was provided with lateral fins; the arms were eight, furnished with horny hooks, with two "tentacles"; and probably the mouth was provided with horny mandibles. An ink-bag was present. The internal skeleton of a *Belemnite* (fig. 294) consists of a chambered cone—the "phragmacone"—the septa of which are pierced by a marginal tube or "siphuncle." In the last chamber of the phragmacone is contained the ink-bag, often in a well-preserved condition. Anteriorly the phragmacone is continued into a horny lamina or "pen" (the "pro-ostracum" of Huxley), and posteriorly it is lodged in a conical sheath or "alveolus," which is excavated in the substance of a nearly cylindrical, fibrous body, the "guard" (fig. 294, *g*) which projects backwards for a longer or shorter distance, and is the part most usually found in a fossil condition.

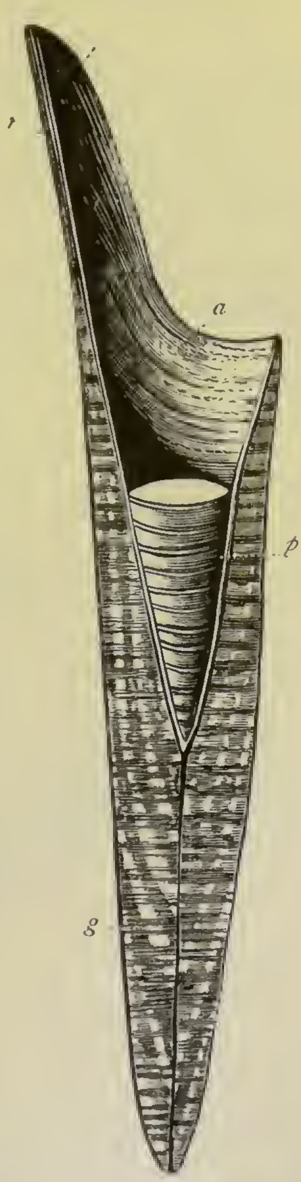

Fig. 294.—Diagram of Belemnite (after Professor Phillips). *r* Horny pen or "pro-ostracum"; *p* Chambered "phragmacone" in its cavity or "alveolus" (*a*); *g* "Guard."

ORDER II. TETRABRANCHIATA.—The members of this order of the *Cephalopoda* are characterised by being *creeping animals, protected by an external, many-chambered shell, the septa between the chambers of which are perforated by a membranous or calcareous tube termed the "siphuncle." The arms are numerous and are devoid of suckers; the branchiæ are four in number, two on each side of the body; the funnel does not form a complete tube; and there is no ink-bag.*

Though abundantly represented by many and varied extinct forms, the only living member of the *Tetrabranchiata* is the Pearly Nautilus, which has been long known by its beautiful chambered shell, but the soft parts of which were first described (in 1832) from a perfect specimen which was examined by Professor Owen.

The soft structures in the Pearly Nautilus may be divided into a posterior, soft, membranous mass (*metasoma*), containing the viscera, and an anterior muscular division, comprising the head (*prosoma*); the whole being contained in the capacious outermost chamber (the body-chamber) of the shell, from which the head can be protruded at will. The shell itself (fig. 295) is involuted and many-chambered, the animal being con-

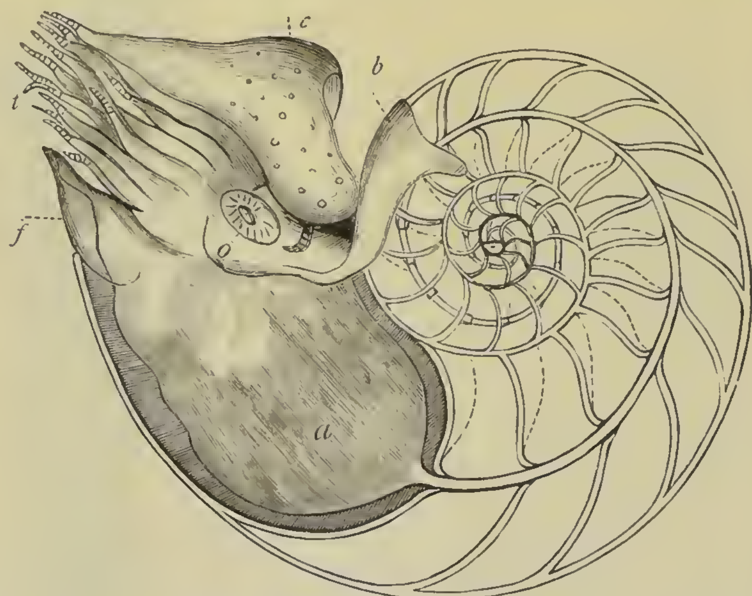

Fig. 295.—Pearly Nautilus (*Nautilus pompilius*). *a* Mantle; *b* Its dorsal fold; *c* Hood; *o* Eye; *t* Tentacles; *f* Funnel.

tained successively in each chamber, and retiring from it as its size becomes sufficiently great to necessitate the acquisition of more room. Each chamber, as the animal retires from it, is walled off by a curved, nacreous septum; the communication between the chambers being still kept up by a membranous tube or siphuncle, which opens at one extremity into the pericardium, and is continued through the entire length of the shell. The position of the siphuncle is in the centre of each septum, but the siphuncle simply passes through the chambers, without opening into them.

Posteriorly the mantle of the Nautilus is very thin, but it is

much thicker in front, and forms a thick fold or collar surrounding the head and its appendages. From the sides of the head spring a great number of muscular prehensile processes or "arms" ("tentacles"), which are annulated, but are not provided with cups or suckers. It is questionable if these structures really correspond morphologically with the "arms" of Cuttle-fishes, and they are therefore best spoken of as "tentacles." The two dorsal tentacles are fused with one another, and form a sort of hood, which can be employed to close the mouth of the shell. Four of the tentacles of the male are specially modified to form a peculiar organ termed the "spadix," which is connected with reproduction, and corresponds with the "hectocotylised" arm of the male Cuttle-fishes. In the centre of the head is the mouth, surrounded by a circular fleshy lip, external to which is a series of labial processes. The mouth opens into a buccal cavity, armed with two horny mandibles, partially calcified towards their extremities, and shaped like the beak of a parrot, except that the under mandible is the longest. There is also a "tongue," which is fleshy and sentient in front, but is armed with recurved teeth behind. The gullet opens into a large crop, which in turn conducts to a gizzard, and the intestine terminates at the base of the funnel. On each side of the crop is a well-developed liver.

The heart is contained in a large pericardial chamber, and in correspondence with the number of gills there are four auricles; but there are no "branchial hearts." The respiratory organs are in the form of four pyramidal branchiæ, two on each side of the mantle-cavity.

The chief masses of the nervous system are the cerebral and infra-œsophageal ganglia, which are partially protected by a cartilaginous plate, which is to be regarded as a rudimentary cranium, and which sends out processes for the attachment of muscles. The organs of sense are two large eyes, attached by short stalks to the sides of the head, two spheroidal ear-capsules, and two hollow plicated subocular processes, believed to be possibly olfactory in their function.

The reproductive organs of the female consist of an ovary, with accessory nidamental glands; the oviducts being paired, right and left, but the left duct being rudimentary (Lankester and Bourne).

There is no ink-bag, and the funnel does not form a complete tube, but consists of two muscular lobes, which are simply in apposition. It is the organ by which swimming is effected, the animal being propelled through the water by

means of the reaction produced by the successive jets emitted from the funnel. The function of the chambers of the shell appears to be that of reducing the specific gravity of the animal to near that of the surrounding water, since they are most probably filled with some gas secreted by the animal. Good authorities, however, believe that the chambers of the shell are filled with water. The function of the siphuncle is unknown, except in so far as it doubtless serves to maintain the vitality of the shell.

SHELL OF THE TETRABRANCHIATA.—The shells of all the *Tetrabranchiata* agree in the following points :—

1. The shell is external.

2. The shell is divided into a series of chambers by plates or "septa," the edges of which, where they appear on the surface of the shell, are termed the "sutures."

3. The outermost chamber of the shell is the largest, and is the one inhabited by the animal.

4. The various chambers of the shell are traversed by a tube, termed the "siphuncle."

Agreeing in all these fundamental points of structure, two very distinct types of shell may be distinguished as characteristic of the two families *Nautilidæ* and *Ammonitidæ*, into which the order *Tetrabranchiata* is divided.

In the family *Nautilidæ* (fig. 296, *d* and *e*), the "septa" of

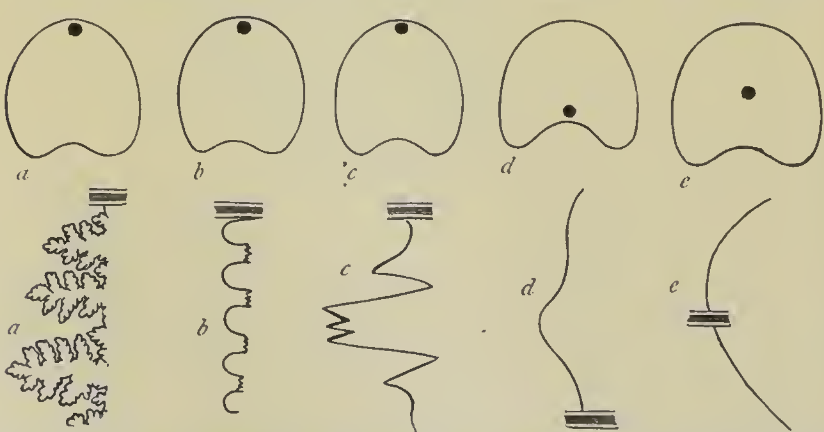

Fig. 296.—Diagram to illustrate the position of the siphuncle and the form of the septa in various Tetrabranchiate Cephalopoda. The upper row of figures represents transverse sections of the shells, the lower row represents the edges of the septa. *a a Ammonite* or *Baculite*; *b b Ceratite*; *c c Goniatite*; *d d Clymenia*; *e e Nautilus* or *Orthoceras*.

the shell are simple, curved, or slightly lobed; the "sutures" are more or less completely plain; and the "siphuncle" is central, sub-central, or internal (*i.e.*, on the *concave* side of the curved shells).

In the family *Ammonitidæ* (fig. 296, *a*, *b*, and *c*), on the other hand, the septa are folded and complex; the sutures are angulated, zigzag, lobed, or foliaceous; and the siphuncle is external (*i.e.*, on the *convex* side of the curved shells).

In both these great *types* of shell, a series of representative *forms* exists, resembling each other in the manner in which the shell is folded or coiled, but differing in their fundamental structure. All these different forms may be looked upon as produced by the modification of a greatly elongated cone, the structure of which may be in conformity with the type either of the *Nautilidæ* or of the *Ammonitidæ*. The following table (after Woodward) exhibits the representative forms in the two families :—

	Nautilidæ.	*Ammonitidæ*.
Shell straight, ...	Orthoceras, .	Baculites.
,, bent on itself, . . .	Ascoceras, . .	Ptychoceras.
,, curved, ...	Cyrtoceras, .	Toxoceras.
,, spiral, ...	Trochoceras, .	Turrilites.
,, discoidal, ...	Gyroceras, . .	Crioceras.
,, discoidal and produced,	Lituites, . . .	Ancyloceras.
,, involute, ...	Nautilus, . .	Ammonites.

After *Nautilus* itself, the most important form of the *Nautilidæ* is the *Orthoceras* (figs. 297, 298). In structure this was doubtless essentially identical with the Nautilus, but the shell, instead of being coiled into a spiral lying in one plane, was extended in a straight, or nearly straight, line. Orthoceratites of more than six feet in length have been discovered, but in all, the body-chamber, in which the animal was lodged, appears to have been comparatively small. The siphuncle is sometimes complex in structure, and was calcareous throughout its entire length.

The structure of the shell in the *Ammonitidæ* is exactly that of the Pearly Nautilus, consisting of an outer porcellanous and an inner nacreous layer. The body-chamber was rather elongated than laterally expanded or dilated. The simplest form of the *Ammonitidæ* is the *Baculite*, in which the shell is straight, like that of an *Orthoceras*, while the septa have the characters of those of an *Ammonite*, and the siphuncle is external. In the *Turrilite* (fig. 300) the structure of the shell is the same, but it is coiled into a turreted spiral. In *Ammonites* itself (fig. 299), the shell is discoidal and involuted, corresponding (in *form*) to the shell of the *Nautilus*; the body-chamber was of comparatively large size, and had its aperture closed, in some species at any rate, by an operculum. The

shell sometimes attained a gigantic size, and several hundred species of the genus have been described. In *Crioceras* (fig. 300) the shell was a flat spiral, like that of the Ammonites,

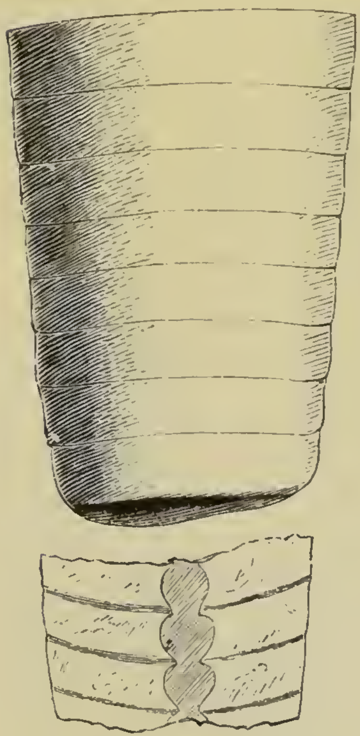

Fig. 297.—Fragment of *Orthoceras* (*Ormoceras*) *crebriseptum* — Cincinnati Group, North America, of the natural size. The lower figure is a section showing the air-chambers, and the form and position of the siphuncle. (After Billings.)

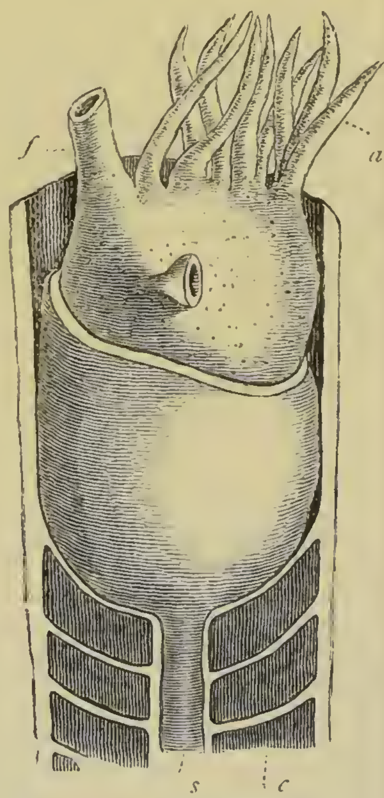

Fig. 298.—Restoration of *Orthoceras*, the shell being supposed to be divided vertically, and only its upper part being shown. *a* Arms; *f* Muscular tube ("funnel") by which water is expelled from the mantle-chamber; *c* Air-chambers; *s* Siphuncle.

but the whorls are not in contact. In *Toxoceras* the shell is shaped like a bow. In *Ancyloceras* (fig. 300) the shell is at first discoidal, with separate whorls, then produced into a straight line, and finally bent forwards into a hook.

Distribution of the Cephalopoda in Space.—All the *Cephalopoda*, without exception, are marine. Some of the Cuttle-fishes (such as the *Octopi* and *Sepiæ*) live in the vicinity of land, especially frequenting rocky bottoms; while others (such as *Argonauta*, *Spirula*, *Sepiola*, *Onychoteuthis*, &c.) live in the open sea, often far from land, swimming at or near the surface. Some of the Cuttle-fishes attain a gigantic size; but all these colossal forms of the class appear to belong to the

Decapoda. The *Architeuthis* of the North Atlantic is certainly known to attain a length of 15 feet or upwards to the body and head, and from 30 to 40 feet or more in the long tentacles.

Fig. 299.—*Ammonites bifrons*, from the Lias

The Pearly Nautilus is confined to the Pacific and Indian Oceans, and appears to live in tolerably deep water (200 to 300 fathoms).

DISTRIBUTION OF CEPHALOPODA IN TIME.—The Cephalopods are largely represented in all the primary groups of stratified rocks from the Upper Cambrian up to the present day. Of the two orders of *Cephalopoda*, that of the *Tetrabranchiata* is the oldest, attaining its maximum in the Palæozoic period, decreasing in the Mesozoic and Kainozoic epochs, and being represented at the present day by the single form *Nautilus pompilius*, together with some varieties or nearly allied species. Of the sections of this order, the *Nautilidæ* proper and the *Orthoceratidæ* are pre-eminently Palæozoic, and the *Ammonitidæ* are not only pre-eminently, but are almost exclusively, Secondary. Of the abundance of the two former families in the Silurian seas some idea may be obtained when it is mentioned that over a thousand species have been described by M. Barrande from the Silurian basin of Bohemia alone. The *Nautilidæ* proper have gradually decreased in numbers from the Palæozoic through the Secondary and Tertiary periods to the present day. The *Orthoceratidæ* died out much sooner, being exclusively Palæozoic, with the exception of the genera *Orthoceras* itself and *Cyrtoceras*, which survived into the commencement of the Secondary period, finally dying out in the Trias.

The second family of the *Tetrabranchiata*—viz., that of the

Ammonitidæ — is almost exclusively Secondary, being very largely represented by numerous species of the genera *Ammonites*, *Ceratites*, *Baculites*, *Turrilites*, &c. The principal Palæozoic genera are *Goniatites* and *Bactrites*, of which the former is found from the Silurian to the Trias, whilst the latter is

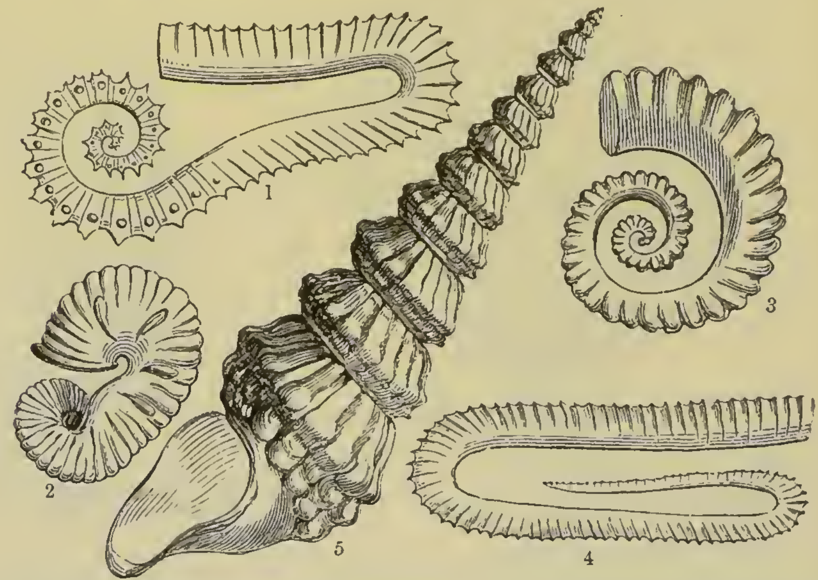

Fig. 300.—Shells of Secondary Cephalopods. 1. *Ancyloceras Matheronianus*; 2. *Scaphites æqualis*; 3. *Crioceras Duvalii*; 4. *Hamites attenuatus*; 5. *Turrilites catenatus*.

a Devonian form; but true Ammonites have been found in strata of Carboniferous age in India (Dr Waagen). The genus *Ceratites* is characteristically Triassic, but allied forms occur in Permo-Carboniferous strata. All the remaining genera are exclusively Secondary, the genera *Baculites*, *Turrilites*, *Hamites*, and *Ptychoceras* being confined to the Cretaceous period. The only genus which passes up into the Tertiary is *Ammonites*, which occurs in beds believed to be of this age in America.

Of the Dibranchiate Cephalopoda the record is less perfect, as these have few structures which are capable of preservation. They attain their maximum, as fossils, shortly after their first appearance in the Secondary rocks, where they are represented by the large and important family of the *Belemnitidæ*. Some of the *Teuthidæ* and *Sepiadæ* are found both in the Secondary and in the Tertiary rocks, and two species of Argonaut have been discovered in the later Tertiaries. No example of a Dibranchiate Cephalopod is known from the Palæozoic deposits, and the order attains its maximum at the present day.

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CHAPTER XLV.

TUNICATA.

BEFORE passing on to the Vertebrates, we may here consider briefly the remarkable group of animals which are known as the Tunicates, and which have been variously regarded as an aberrant group of the *Mollusca*, or as a degenerate type of the *Vertebrata*. The Tunicates are *simple or compound, and have the body enclosed in a saccular integumentary investment, which is perforated by two openings. One of the apertures in the outer covering of the animal leads into a dilated pharyngeal sac, the walls of which are perforated by numerous slits, leading into a second chamber* ("*atrium*") *which communicates with the exterior by the other aperture in the integument. The pharyngeal sac is respiratory in function, and conducts into an alimentary canal which opens into the atrial chamber. The heart is in the form of a simple tube open at both ends. The sexes are united in the same individual, and there is in general a metamorphosis in development, the larva possessing a structure comparable to the notochord of Vertebrates.*

The Tunicates or Ascidians are all inhabitants of the sea, and may be either simple or compound. The general structure of the group is best understood by taking one of its simple members as a type. In external appearance a solitary

Ascidian may be compared to a double-necked jar (figs. 301, 302), with two prominent apertures, which are situated near one another towards the anterior end of the animal. In some cases (*Salpa*) the two apertures are placed at opposite ends of the body. In the ordinary forms, the posterior end of the

Fig. 301.—Tunicata. A, *Ascidia lata*, seen from the right side, of the natural size: *b* Branchial aperture; *a* Atrial aperture. B, Part of the branchial sac of the same, seen from the inside, magnified. C, Part of the branchial sac of *Ascidia virginea* (= *Ascidia sordida*), seen from the inside, magnified. (After Herdman.)

body is attached to some foreign body. The outer covering of the body of an Ascidian is composed of two layers, an external and internal. The former of these—termed the "test"—is often of considerable thickness, commonly transparent or semi-transparent, and usually of a coriaceous or cartilaginous

consistence. It is remarkable as containing a substance apparently identical with the cellulose of vegetables, and it is in reality composed of an abnormal form of connective tissue. It is lined by an ectodermal layer of cells, and spicules of a siliceous or calcareous nature are sometimes developed in it. The test forms a common matrix ("investing mass") in which the zoöids of the composite Tunicates are embedded, while it is only present at certain times in *Appendicularia*, and is wanting in some forms of *Doliolum*.

The "test" is lined by an internal layer, which is spoken of as the "second tunic" or "mantle," and which is composed of connective tissue containing muscular fibres, nerves, and blood-vessels. The mantle is only loosely connected with the test, except in the neighbourhood of the two apertures of the test, but the two coverings are in direct contact during life. The muscular tunic gives the animal great contractility, and

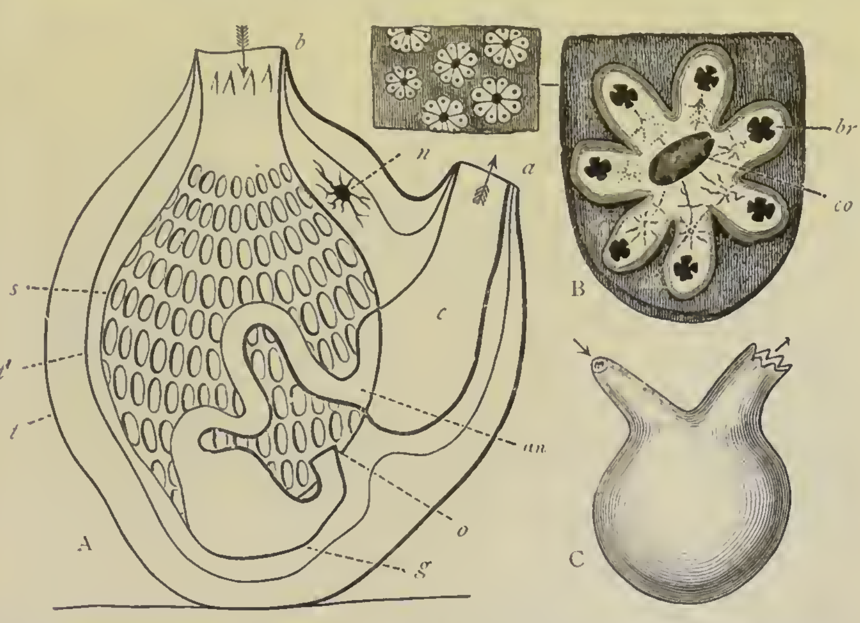

Fig. 302.—Morphology of *Tunicata*. A, Diagram of the structure of a simple Tunicate: *t* Test; *t'* Second muscular tunic; *s* Branchial sac; *b* Branchial aperture; *a* Atrial aperture; *c* Atrium; *o* Opening of the gullet; *g* Stomach, leading into the intestine; *an* Anal aperture; *n* Nerve-ganglion. B, *Botryllus smaragdus*—a small portion of a colony of the natural size, and a single system of the same enlarged: *co* Common atrial aperture; *br* Branchial aperture of one of the zoöids. C, *Molgula Manhattensis*, a simple Ascidian. The arrows in A and C show the direction of the water-currents.

enables it to eject the water forcibly from its branchial and cloacal apertures. Hence the name of "Sea-squirts" often given to the Tunicates.

Of the two apertures into the test, the anterior one (figs. 301, 302, *b*) may be regarded as the mouth, and is often furnished internally with a circlet of small, non-ciliated, non-retractile tentacles. It opens into a largely dilated pharynx, which has its walls perforated by numerous apertures (fig. 301, B and C, and 302, A), and discharges the function of a respiratory organ. The pharyngeal or "branchial" sac usually occupies a great part of the cavity of the mantle, and is freely suspended within a second chamber, which is known as the "peribranchial space" or "atrium," and which communicates with the exterior by the second, or "atrial," aperture of the test (figs. 301, 302, *a*). The atrial aperture is placed posteriorly to the branchial aperture, and usually on the dorsal aspect of the body. The atrial chamber includes the whole of the branchial sac, except along a line running longitudinally on the ventral side of the pharynx, and corresponding with the structure termed the "endostyle" (fig. 303, *en*).

The membranous wall of the atrial sac becomes completely incorporated with the wall of the pharyngeal sac, where it wraps round the latter, and the two conjoined lamellæ become perforated by numerous apertures arranged in successive transverse rows (fig. 301, B and C). The margins of these pharyngo-atrial apertures are fringed with cilia, which work towards the atrium; and by the action of these water-currents are produced, which get in by the branchial aperture and out by the atrial opening, and which not only supply oxygen to the blood, but also bring to the animal the minute organisms which constitute its food. The pharyngeal sac is enabled to act as a respiratory organ in virtue of the fact that its walls are composed of a lattice-work of longitudinal and transverse blood-vessels, which bound the ciliated apertures just spoken of, and which open on each side into two main longitudinal sinuses—the so-called "branchial" or "thoracic" sinuses.

The structure termed the "endostyle" (fig. 303, *en*), is a longitudinal ciliated groove, with prominent margins, which is placed along the ventral side of the pharynx, and which has for its function the secretion of mucus. On the dorsal side of the pharynx, opposite to the endostyle, is a peculiar fold-like involution of the wall of the pharynx (fig. 303, *dl*), which is known as the "dorsal lamina" (or "languets").

At the bottom of the pharyngeal sac is situated the opening of the œsophagus (fig. 302, A, *o*), which conducts to a capacious stomach. From the stomach an intestine is continued, generally with few flexures, to the anal aperture, which opens into the atrium, excrementitious matters thus being discharged

along with the outgoing currents of water from the atrial aperture of the test. The atrium is for this reason often spoken of as the "cloaca." The stomach and intestine almost always lie on one side of the branchial sac, usually the left, and the first bend of the intestine is "hæmal," or is directed towards that side of the body on which the heart is situated. Glandular organs which may represent the liver are often present, and there are also organs which are supposed to have a renal function.

The heart is a simple sac or fusiform tube, enclosed in a

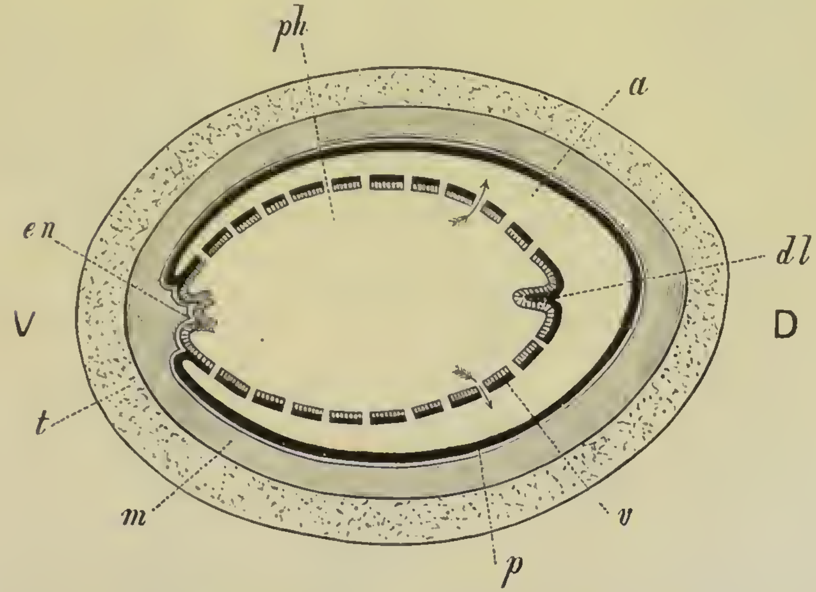

Fig. 303.—Diagrammatic cross-section of an Ascidian towards its anterior end, to show the relation of the pharyngeal sac to the atrial membrane. *t* Test; *m* Second tunic or "mantle"; *p* Parietal layer of the atrial membrane; *v* Visceral layer of the atrial membrane, incorporated with the proper wall of the pharynx, the conjoined lamellæ being perforated by the respiratory pores (the atrial membrane is represented by the thick black line, and the wall of the pharynx is cross-shaded; the arrows show the direction of the currents of water); *ph* Cavity of the pharyngeal sac; *a* Cavity of the atrium; *en* Endostyle; *dl* Dorsal lamina. The processes which connect the branchial sac with the mantle are omitted. V, Ventral side; D, Dorsal side. (Altered from Herdman).

pericardium, and giving off vessels at both ends. The circulation exhibits the remarkable peculiarity of being periodically reversed, the blood being propelled in one direction for a certain number of contractions, and being then driven for a like period in an opposite direction; "so that the two ends of the heart are alternately arterial and venous" (Huxley).

The nervous system consists of a single ganglion placed on the dorsal side of the mouth (fig. 302, *n*). In the aberrant

genus *Appendicularia*, in which the tail of the larva is persistent, this ganglion is connected with a second ganglion which is placed at the base of the tail, and which gives off a nervous cord to the latter. The principal sense-organs are the tentacles placed at the entrance of the branchial sac, and minute pigment-spots or "ocelli" placed round the branchial and atrial apertures.

The so-called "olfactory gland," or "hypophysial gland," is not an organ of sense. It consists of a tubular gland, which lies underneath the nerve-ganglion, and the duct of which terminates on the so-called "olfactory tubercle," at the anterior end of the branchial sac, on the dorsal side. This curious organ has been compared with the "pituitary body" of Vertebrates.

The sexes are united in the same individual in all the Tunicates. The reproductive organs lie in the fold of the intestine, and their ducts open into the atrial chamber. In *Appendicularia* the generative glands are ductless, and in the *Salpæ* the male organs are not at first developed. Non-sexual reproduction by means of budding is of very common occurrence, and the phenomena attending it are often of considerable complexity.

The embryo Tunicate (fig. 304, A and C) generally passes through a free and locomotive phase, in which it is shaped like the tadpole of a Frog, and swims by means of a long caudal appendage. In some cases, however (*e.g.*, *Molgula*), the larva is destitute of a tail, and there is no metamorphosis. The larval tail is especially remarkable as containing a primitive neural canal, in the floor of which is developed a cellular rod-like structure, which resembles the notochord of Vertebrates. Ultimately, the larva in the majority of cases attaches itself to some foreign body by means of processes developed at one end of the body; a mouth is developed at the opposite extremity; and the embryonic tail, with its contained structures, is wholly lost. In *Appendicularia* alone the larval tail is persistent.

The following * are the more important developmental changes exhibited in the simple Ascidians generally, as worked out by the researches of Kowalewsky and others:—

(1.) The segmented ovum gives rise to a double-layered embryo or "gastrula," the primitive mouth ("blastopore") of which is placed at the posterior end of the body—*i.e.*, at the end of the body which is destined to become ultimately the fixed end.

* See Balfour's 'Treatise on Comparative Embryology,' vol. ii. p. 8 *et seq.*

(2.) The dorsal side of the embryo next becomes flattened, and a groove ("medullary groove") is formed upon it, which soon becomes converted, by the upward growth and fusion of its bounding walls, into a closed tube, which communicates with the primitive mouth in front. There is thus formed a primitive "neural canal," as in the embryo of Vertebrates.

(3.) The cells forming the floor of this primitive neural canal for the posterior half of its extent become modified to form a rod-like cellular structure, corresponding with the "notochord" of Vertebrates. This is

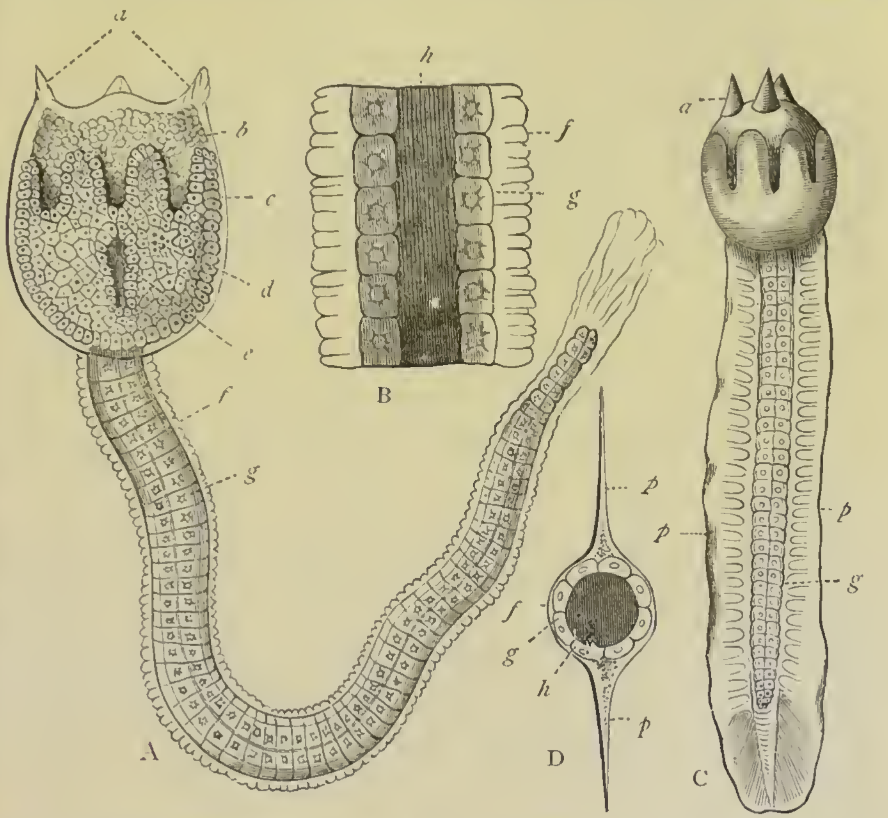

Fig. 304.—Development of *Tunicata*. A, Larva of *Botryllus violaceus*, greatly magnified: *a* Processes for attachment; *b* Mass of primitive cells from which the digestive organs are developed; *c* Circlet of eight cellular outgrowths; *d* Eye-spot; *e* Entrance to the branchial sac; *f* The external structureless "test"; *g* Large nucleated cells forming the sheath of the central axis (eight rows of these cells are present). B, A portion of the tail, highly magnified: *h* Central axis, (*f* and *g*, as before). C, Another larva of the same, viewed from the side, and highly magnified, showing the superior and inferior fin-like prolongations (*p p*) of the "test," with ray-like striæ, (the other letters as before). D, Diagrammatic cross-section of the tail, showing the position of the fins (*p p*), and the relations to one another of the central axis (*h*), the intermediate cellular sheath (*g*), and the external structureless test (*f*). (After Reichert.)

not, however, prolonged into the anterior half of the larva. The larva is now furnished with a long caudal appendage. In process of growth, lateral muscles are developed in connection with the notochord; and the neural tube exhibits an anterior dilatation which may be compared with the cerebral dilatation of the neural canal of Vertebrates.

(4.) The "test" is next formed as a cuticular deposit of epiblast cells, and there grow out from the posterior end of the body (which is at this

stage the anterior end) three papillæ (fig. 304, *a*), which secrete a glutinous fluid and are destined to act as organs of attachment.

(5.) When the larva is hatched, an auditory organ and an unpaired eye are developed in the front part of the neural canal; and a nervous cord, which may be compared with the spinal cord of Vertebrates, is developed in the posterior part of the same.

(6.) The alimentary canal and branchial sac of the adult are next developed, and the atrial cavity appears as a pair of saccular involutions of the outer (epiblastic) layer of the body, which grow inwards and fuse with the branchial sac.

(7.) The larva now attaches itself to some foreign body by one of the three posterior papillæ before mentioned. The larval tail, and with it the notochord, becomes atrophied and disappears (except in *Appendicularia*). The nervous system simultaneously undergoes retrogressive metamorphosis, the anterior portion of the dorsal cord ("spinal cord") alone persisting as the nerve-ganglion of the adult. A mouth is formed at the free or anterior end of the body—*i.e.*, at the end opposite to that at which the primitive mouth was placed. Lastly, the primitive branchial fissures become much more numerous, and the two original atrial sacs coalesce to form the single cloacal sac of the adult.

The Tunicates present themselves under very varied types of structure, and often exhibit very remarkable phenomena in the way of non-sexual reproduction and alternation of generations. The following groups may be distinguished among the *Tunicata*:—

(1.) *Simple Ascidians.*—These consist typically of solitary animals (fig. 301, A, and 302, C), each of which is included in a complete test, furnished with branchial and atrial apertures. The adult is usually fixed to some foreign body, but may be non-adherent. Well-known and widely-distributed genera are *Ascidia*, *Ciona*, and *Styela* (*Cynthia*).

(2.) *Social Ascidians.*—These are very closely allied to the preceding, and are, indeed, essentially identical in anatomical structure. The original animal, however, gives out branched root-like prolongations, or "stolons," from its test, through which the blood circulates, and from which new zoöids are budded out. The principal genera of this group are *Clavellina* and *Perophora*.

(3.) *Compound Ascidians.*—These are forms in which the original animal produces by budding a colony ("ascidiarium") consisting of numerous zoöids ("ascidiozoöids"), which become aggregated into a common growth by an "investing mass" composed of the fused tests of the members of the colony. The separate zoöids may be irregularly scattered through the colony, or they may be arranged in definite groups or "systems"; and they essentially resemble simple Ascidians in anatomical structure. Most of the composite Ascidians are fixed to foreign bodies by their common test. Familiar examples are the *Botrylli* (fig. 302, B), which form semi-transparent crusts, often of brilliant colours, attached to submarine objects, and consisting of numerous zoöids arranged in star-like groups, the members of each system having a common atrial aperture. In *Pyrosoma*, on the other hand, the colony is free-swimming, and there is a remarkable alternation of generations.

(4.) *Salpiform Ascidians.*—These include the aberrant genera *Salpa* and *Doliolum*, comprising transparent, barrel-shaped, free-swimming oceanic Tunicates, in which the branchial and atrial openings are terminal and are

placed at opposite ends of the body. There is an alternation of generations which in the case of *Doliolum* is very complex. In the *Salpæ* the organism occurs in two well-marked alternating generations, each of which produces the other. The one generation consists of solitary individuals which have no reproductive organs, but give rise by budding to the second generation, consisting of sexual individuals united in chains and moving in a serpentine manner through the water. The associated forms are produced as a chain of embryos developed in the interior of a solitary form; and each zoöid of the liberated chain develops a solitary embryo which is attached to the interior of its atrial sac by a sort of placenta, and is ultimately detached as a solitary being.

(5.) *Perennichordate Ascidians.*—In this group are only the aberrant genus *Appendicularia*, and some allied forms, comprising small oceanic Tunicates, in which alone, of all the forms of the class, the larval tail and notochord are persistent. The animal is, therefore, tadpole-like, and its "test" is only developed from time to time, and is not permanent. There is an additional ganglion at the root of the caudal appendage, and a nervous cord is continued backwards from this. The anus opens directly on the exterior, and the generative glands are ductless.

As regards their *distribution in space*, the Tunicates are exclusively marine, and are principally littoral and shallow-water forms, though some are found at considerable depths, and many are pelagic in habit. The singular *Salpidæ* have the branchial and atrial apertures placed at opposite ends of the body, and are found swimming in the open sea, often in immense shoals. The *Appendiculariæ*, with their permanent larval tails, are likewise oceanic, as is the cask-shaped *Doliolum.* Lastly, in *Pyrosoma*, we have a singular compound oceanic Tunicate, in which the numerous zoöids form a tubular colony, which is propelled through the water by the united excurrent respiratory jets of its component members. Like the Salpians, it is brilliantly phosphorescent.

On the other hand, the more typical Tunicates are found attached to all kinds of submarine objects, or (as in *Pelonaia*) embedded in mud.

During the "Challenger expedition," some singular deep-sea Tunicates were obtained, and have been since described by Prof. Moseley. One of these (*Hypobythius*) was found in the Pacific, at a depth of nearly 3000 fathoms, attached to foreign objects by a peduncle. Its test is hyaline and transparent, and is strengthened by symmetrically disposed cartilaginous plates. *Octacnemus*, dredged at over 1000 fathoms, is also hyaline and transparent, with a short stalk, but it possesses eight long radiating processes, which give it a stellate appearance; and the branchial sac is so flattened as to become nearly horizontal.

No Tunicates are known with certainty to have been preserved in the fossil condition.

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VERTEBRATE ANIMALS.

CHAPTER XLVI.

General Characters and Divisions of the Vertebrata.

The six sub-kingdoms which we have previously considered—viz., the *Protozoa*, *Porifera*, *Cœlenterata*, *Echinodermata*, *Annulosa*, and *Mollusca*—together with the groups of the Molluscoids and Tunicates, were grouped together by the French naturalist Lamarck to form one great division, which he termed *Invertebrata*, the remaining members of the animal kingdom constituting the division *Vertebrata*. The division *Vertebrata*, though including only a single sub-kingdom, is so compact and well-marked a division, and its distinctive characters are so numerous and so important, that this mode of looking at the animal kingdom is, at any rate, a very convenient one.

The sub-kingdom *Vertebrata* may be shortly defined as comprising *bilaterally symmetrical animals, devoid of external segmentation, but showing more or less clearly in their internal structure a composition of the body out of longitudinally arranged segments. The main masses of the nervous system are dorsal, and are always shut off from the visceral tube. The cerebro-spinal nerve-axis is underlaid by the structure known as the "notochord," which, in adult life, is generally more or less completely replaced by the cartilaginous or bony axis known as the "vertebral column." Limbs may be wanting; but when present, they are never more than two pairs in number, and they are always turned away from the neural aspect of the body.* These characters distinguish the *Vertebrata*, as a whole, from the

Invertebrata; but it is necessary to define these broad differences more minutely, and to consider others which are of little less importance.

One of the most obvious, as it is one of the most fundamental, of the distinctive characters of *Vertebrates,* is to be found in the shutting off of the main masses of the nervous system from the general cavity of the body. In all adult *Invertebrate* animals, without exception, the body (fig. 305, A) may be regarded as a *single* tube, enclosing all the viscera; and

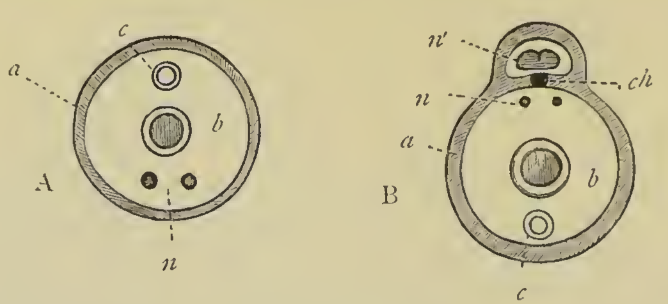

Fig. 305.—A, Transverse section of the body of one of the higher *Invertebrata: a* Body-wall; *b* Alimentary canal; *c* Hæmal system; *n* Nervous system. B, Transverse section of the body of a *Vertebrate* animal: *a* Body-wall; *b* Alimentary canal; *c* Hæmal system; *n* Sympathetic system of nerves; *n'* Cerebro-spinal system of nerves; *ch* Notochord.

consequently, in this case, the nervous system is contained within the general cavity of the body, and is not in any way shut off from the alimentary canal. The transverse section, however, of a *Vertebrate* animal exhibits *two* tubes (fig. 305, B), one of which contains the great masses of the nervous system —that is, the cerebro-spinal axis, or brain and spinal cord —whilst the other contains the alimentary canal and the chief circulatory organs, together with certain portions of the nervous system known as the "ganglionic or "sympathetic" system. The "neural" tube, containing the great nerve-centres, is placed on the dorsal side of the body, while the visceral tube, containing the alimentary canal, heart, and other organs of vegetative life, is situated ventrally.

Not only are the great nerve-centres in this way completely shut off from the viscera, but they are developed in a tube, which is, to begin with, a mere groove on the exterior surface of the embryo. At an early period in the development of the embryo of any Vertebrate animal, the portion of the ovum in which development is going on—the "blastoderm"—becomes elevated into two parallel ridges, one on each side of the middle line, enclosing between them a long groove, which is

known as the "medullary groove"* (fig. 306, *c*). The ridges which bound the medullary groove are known as the "laminæ dorsales" (fig. 306, B, *d*), and they become more and more raised up, till ultimately, bending over, they meet in the middle

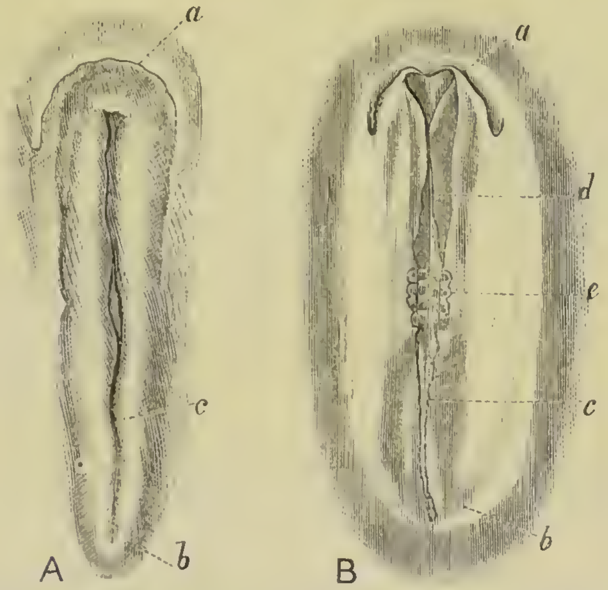

Fig. 306.—Early stages of the development of a Fowl (after Huxley). A, The germinal area, enlarged, showing the medullary groove (*c*). B, The blastoderm with the development further advanced: *c* Medullary groove; *a* Cephalic end of the medullary groove; *b* Caudal end of the same; *d* The "dorsal laminæ," as yet only developed in the cephalic region, and not quite united in the middle line; *e* Protovertebræ.

line, and unite to form a tube, within which the cerebro-spinal nerve-axis developed. It follows from its mode of formation that the inner wall of the tube formed by the medullary groove, which remains as the partition between the cerebro-spinal canal and the body-cavity, is nothing more than a portion of the primitive wall of the body of the embryo.

Another remarkable peculiarity as regards the nervous system is found in the fact, as pointed out by Professor Huxley, that in no Vertebrate animal does the alimentary canal pierce the main masses of the nervous system, but turns away to open on the opposite side of the body. In most Invertebrates, on the other hand, in which there is a well-developed nervous system, this is perforated by the gullet, so that an œsophageal

* The longitudinal furrow, known as the "primitive groove," appears in the posterior part of the blastoderm, and prior to the formation of the medullary groove; but it disappears at an early period of development "without entering directly into the formation of any part of the future animal."—(Foster and Balfour).

nerve-collar is formed, and some of the nervous centres become præ-œsophageal, whilst others are post-œsophageal.

Furthermore, the floor of the "medullary groove" in the embryo of all Vertebrates has developed in it at an early period the structure known as the "notochord" or "chorda dorsalis" (fig. 305, B, *ch*). This structure, so characteristic of Vertebrates, is a cellular rod-like axis, which tapers at both ends, and extends along the floor of the cerebro-spinal canal, supporting the cerebro-spinal nervous centres. In some Vertebrates, such as the Lancelet (*Amphioxus*), the notochord is persistent throughout life. In the majority of cases, however, the notochord is replaced before maturity by the structure known as the "vertebral column" or "backbone," from which the sub-kingdom *Vertebrata* originally derived its name. This is not the place for an anatomical description of the spinal column, and it is sufficient to state here that it is essentially composed of a series of cartilaginous, or more or less completely ossified, segments or *vertebræ*, arranged so as to form a longitudinal axis, which protects the great masses of the nervous system. It is to be remembered, however, that all Vertebrate animals do not possess a vertebral column. They all possess a *notochord*; but this may be persistent, and in many cases the development of the spinal column is extremely imperfect.

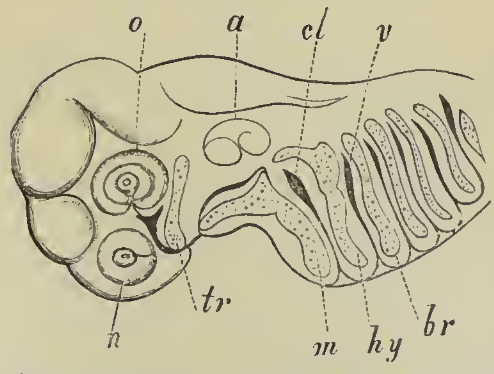

Fig. 307.—Side-view of the head of an embryo Dog-fish (after Parker). *tr* One of the cartilaginous rods ("trabeculæ cranii") developed in the floor of the skull; *m* The first visceral arch, constituting the lower jaw or "mandible"; *hy* The second visceral arch, constituting the hyoid arch; *br* The third visceral arch, constituting the first of the "branchial arches"; *cl* The "hyomandibular cleft"; *v* The first "branchial cleft"; *n* Rudiment of the olfactory organ; *o* Eye; *a* Auditory mass.

Another embryonic structure, which is characteristic of all Vertebrates, is found in the so-called "visceral arches" and "clefts" (fig. 307). The "visceral arches" are a series of parallel ridges running transversely to the axis of the body, situated at the sides of, and posterior to, the mouth. As development proceeds, the intervals between these ridges become grooved by depressions which gradually deepen, until they become converted into a series of openings or "clefts," whereby a free communication is established between the upper part of the alimentary

canal (pharynx) and the external medium. In Fishes and many Amphibians the greater number of the visceral clefts remain open throughout life; and the visceral arches of all fishes (except the Lancelet) throw out filamentous or lamellar processes, which receive branches of the branchial artery and constitute branchiæ. In the Abranchiate Vertebrates (Reptiles, Birds, and Mammals), branchial processes are never developed upon any of the visceral arches, and the visceral clefts become closed, the first cleft alone being partially preserved as the *meatus auditorius externus*. The first visceral arch becomes converted into the lower jaw or "mandible" (fig. 307, *m*); and the second becomes the "hyoid arch" (fig. 307, *hy*). The remaining arches, with the partial exception of the most anterior one (the third arch), disappear in air-breathing Vertebrates, but they are persistent in Fishes, and constitute the so-called "branchial arches."

The limbs of Vertebrate animals are always articulated to the body, and they are always turned away from the neural aspect of the body. They may be altogether wanting, or they may be partially undeveloped; but there are never more than two pairs, and they always have an internal skeleton for the attachment of the muscles of the limb.

A specialised blood-vascular or "hæmal" system is present in all the *Vertebrata*; and in all except one—the *Amphioxus*—there is a contractile cavity or *heart*, which never consists of less than two chambers provided with valvular apertures. In all the *Vertebrata* the heart is essentially a *respiratory* heart—that is to say, it is concerned with driving the impure or venous blood to the breathing organs; and in its simplest form (fishes) it is nothing more than this. In the higher Vertebrates, however, there is superadded to this a pair of cavities which are concerned in driving the pure or arterial blood to the body. When this is the case, these two circulations are often spoken of as the "lesser" or "pulmonary" circulation, and the "greater" or "systemic" circulation.

In all Vertebrates there is that peculiar modification of the venous system which is known as the "hepatic portal system." That is to say, a portion of the blood which is sent to the alimentary canal, instead of returning to the heart by the ordinary veins, is carried to the liver by a special vessel—the *vena portæ*—which ramifies through this organ after the manner of an artery. In the majority of the lower Vertebrates (Fishes and Amphibians), the afferent veins of the kidney similarly break up in the substance of this organ, as the portal vein does in the liver, a portion of the venous blood being thus

specially acted upon before being added to the general venous circulation. In these forms, therefore, there exists what is known as a "renal-portal" venous circulation.

In all Vertebrates, also, is found the peculiar system of vessels known as the "lacteal system." This is to be regarded as an appendage of the venous system of blood-vessels, and consists of a series of vessels which take up the products of digestion from the alimentary canal, elaborate them, and finally empty their contents into the veins.

Lastly, the masticatory organs of Vertebrates are modified portions of the walls of the head, and never "hard productions of the alimentary mucous membrane, or modified limbs" (Huxley), as they are amongst the Invertebrates.

The above are the leading characters of the *Vertebrata* as a whole; but before going on to consider the primary divisions of the sub-kingdom, it may be as well to give a very brief and general description of the anatomy of the higher and more typical Vertebrates, commencing with their bony framework, or skeleton.

The hard structures of Vertebrates are partly endoskeletal and partly exoskeletal, the latter being hardenings of the integument or mucous membranes. The endoskeleton in the case of many of the lower Vertebrates does not pass beyond the condition of cartilage; but in the higher groups it is formed by the deposition of phosphate of lime in, or close to, masses of cartilage, and the formation in this way of true osseous tissue. Those bones which, prior to ossification, exist in the condition of cartilage, are known as "cartilage-bones"; whereas those which are not prefigured in cartilage are termed "membrane-bones."

The *endoskeleton* of the *Vertebrata* may be regarded as consisting essentially of the bones which go to form the head and trunk on the one hand (sometimes called the "axial" skeleton), and of those which form the supports for the limbs ("appendicular" skeleton) on the other hand. The bones of the head and trunk may be looked upon as essentially composed of a series of bony rings or segments, arranged longitudinally, one behind the other. Anteriorly these segments are much expanded, and likewise much modified, to form the bony case which encloses the brain, and which is termed the *cranium* or skull. Behind the head the segments enclose a much smaller cavity, which is called the "neural" or spinal canal, as it encloses the spinal cord; and they are arranged one behind the other, forming the vertebral column. The segments which form the vertebral column are called "vertebræ," and they have the

following general structure: Each vertebra (fig. 308, A) consists of a central piece, which is the fundamental and essential element of the vertebra, and is known as the "body" or "centrum" (*c*). From the upper or posterior surface of the centrum spring two bony arches (*n n*), which are called the "neural arches," or "neurapophyses," because they form with the body a canal—the "neural canal"—which encloses the spinal cord. From the point where the neural arches meet behind, there is usually developed a longer or shorter spine, which is termed the "spinous process," or "neural spine" (*s*). From the neural arches there are also developed in the typical vertebra two processes (*a a*), which are known as the "articular" processes,

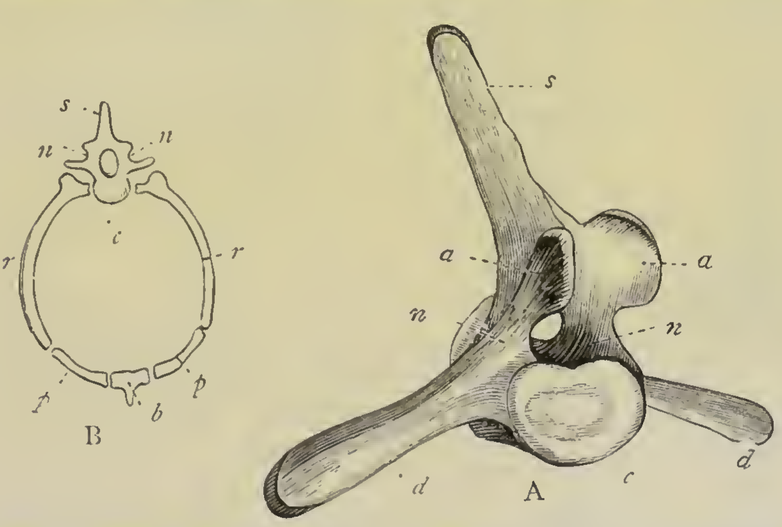

Fig. 308.—A, Lumbar vertebra of a Whale: *c* Body or centrum; *n n* Neural arches; *s* Neural spine; *a a* Articular processes; *d d* Transverse processes. B, Diagram of a thoracic vertebra: *c* Centrum; *n n* Neural arches enclosing the neural canal; *s* Neural spine; *r r* Ribs, assisting in the formation of the hæmal arch; *p p* Costal cartilages; *b* Sternum, with hæmal spine. (After Owen.)

or "zygapophyses." The vertebræ are united to one another partly by these, but to a greater extent by the bodies or "centra." From the sides of the vertebral body, at the point of junction with the neural arches, there proceed two lateral processes (*d d*), which are known as the "transverse processes." (In the typical vertebra the transverse processes consist each of two pieces, an anterior piece or "parapophysis," and a posterior piece or "diapophysis.") These elements form the *vertebra* of the human anatomist, but the "vertebra" of the transcendental anatomist is completed by a second arch which is placed beneath the body of the vertebra and which is called the "hæmal" arch, as it includes and protects the main organs of the circulation. This second arch is often only recognisable

with great difficulty, as its parts are generally much modified, but a good example may be obtained in the Mammalian thorax, or in the caudal vertebra of a Bony Fish.

The hæmal arch in the case of the thorax (fig. 308, B) is formed by the ribs (*r r*) and the costal cartilages (*p p*), and is completed in front by the breast-bone or sternum (*b*), which in some cases—but not in man—develops a spine (the hæmal spine) which corresponds to the neural spine on the opposite aspect of the vertebra.

In the caudal vertebra of a Bony Fish (fig. 309), on the other hand, the centrum (*c*) not only gives off two neural arches (*na*) from its dorsal aspect, but also develops a pair of hæmal arches (*ha*) from its ventral side. The neural arches enclose a neural canal, in which is contained the spinal cord, while the backward continuation of the systemic aorta is contained in the canal formed by the hæmal arches. Each pair of arches, further, develops a spinous process — the "neural spine" and "hæmal spine."

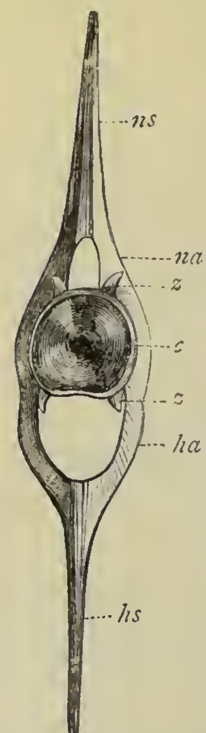

Fig. 309.—One of the caudal vertebræ of a Bony Fish (after Günther). *c* Centrum; *na* Neural arch; *ns* Neural spine; *ha* Hæmal arch; *hs* Hæmal spine; *z z* Articular processes.

It follows from the above, that the typical vertebra consists of a central piece or body from which two arches are given off, one of which protects the great masses of the nervous system, and is therefore said to be "neural"; whilst the other protects the main organs of the circulation, and is therefore said to be "hæmal." The correspondence of the typical bony segment or vertebra with the doubly tubular structure of the body in all Vertebrates is thus too obvious to require to be specially pointed out.

As a general rule, the vertebral column is divisible into a number of distinct regions, of which the following are recognisable in man and in the higher *Vertebrata:* 1. A series of vertebræ which compose the neck, and constitute the "cervical region" of the spine (fig. 310, *c*). 2. A number of vertebræ which usually carry well-developed ribs, and form the "dorsal region" (*d*). 3. A series of vertebræ which form the region of the loins, or "lumbar region" (*l*). 4. A greater or less number of vertebræ which constitute the "sacral region," and are usually amalgamated or "anchylosed" together to form

a single bone, the "sacrum." 5. The spinal column is completed by a variable number of vertebræ which constitute the "caudal" region, or tail (*t*).

The bony or cartilaginous case in which the brain is con-

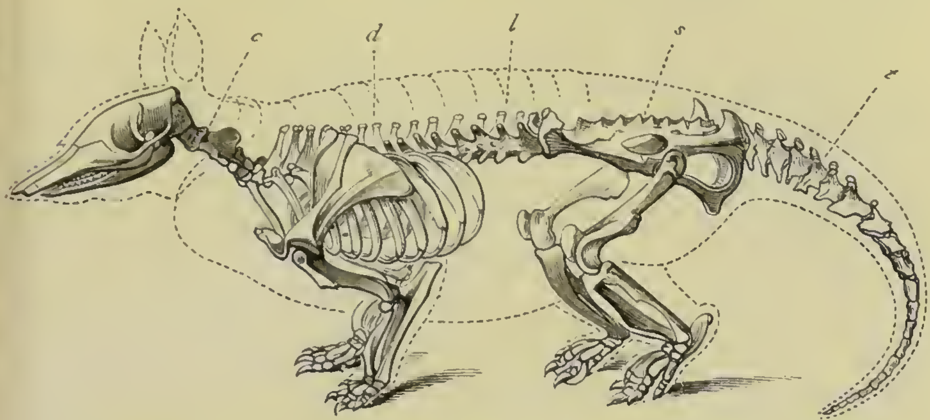

Fig. 310.—Skeleton of an Armadillo, showing the regions of the vertebral column. *c* Cervical region; *d* Dorsal region; *l* Lumbar region; *s* Sacral region; *t* Caudal region or tail.

tained is known as the "cranium," and is wanting in no other Vertebrates except the Lancelet. In addition to the brain-case proper, the "skull" is composed in part of the bony or cartilaginous capsules which enclose and protect the organs of hearing, sight, and smell; while to its inferior surface are usually appended the visceral arches, of which the mandible and hyoid arch alone persist in the higher Vertebrates. The cranium may be regarded as formed of three or four principal segments, which have been regarded by high authorities as homologous with vertebræ.

The segments usually recognised in the skull are the following, from behind forwards:—

(1) The *occipital* segment, formed of the basi-occipital inferiorly, the exoccipitals laterally, and the supra-occipital above, the whole surrounding the "foramen magnum," through which the spinal cord becomes connected with the brain. The elements of the occipital segment may be separate, or may be united to form a single bone (the "occipital bone" of human anatomy).

(2) The *parietal* segment, consisting of the basi-sphenoid inferiorly, the alisphenoids laterally, and the parietal bones above.

The auditory capsule is wedged in between the occipital and parietal segments, and the bones which are ordinarily developed in its walls may remain separate, or may be combined to form a single mass (the "temporal bone" of human anatomy).

(3) The *frontal* segment, consisting of the presphenoid inferiorly, the orbitosphenoids laterally, and the frontal bones superiorly.

(4) The mesethmoid, or central ossification of the ethmoid bone, may be

regarded as representing a fourth segment. On each side of this are placed the nasal sacs, separated from one another by the mesethmoid and vomer, roofed by the nasal bones, and bounded laterally by the pterygoids, maxillæ, præmaxillæ, and lachrymal bones.

The "jugal" (or "malar" bone of human anatomy) is the bone which connects the temporal bone with the maxilla.

The lower jaw or "mandible" of Vertebrates is composed of two halves or "rami," which are united to one another in front, and articulate separately with the skull behind. The two rami are very variously connected with one another, being sometimes only joined by ligaments and muscles, sometimes united by cartilage or by bony suture, or sometimes fused or anchylosed with one another so as to leave no evident traces of their true composition. In the Mammals, each ramus consists only of a single piece (the "dentary" bone). In the lower Vertebrates, on the other hand, each ramus of the mandible consists of more than one piece, typically of six pieces (fig. 311), united to one another by sutures. In the lower

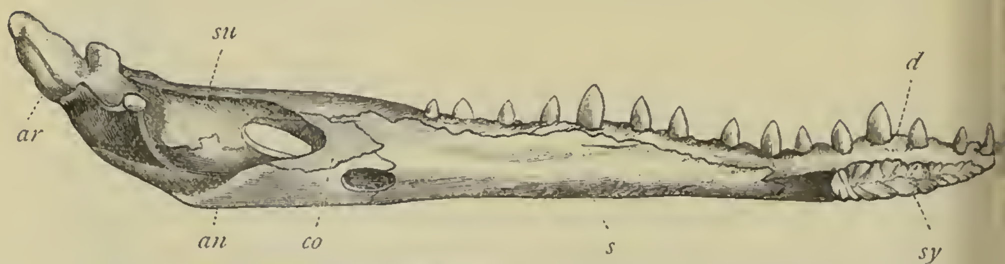

Fig. 311.—The left ramus of the lower jaw of a Crocodile, viewed from the inner side (after Cuvier). *d* "Dentary" bone; *s* "Splenial" bone; *co* "Coronoid"; *an* "Angular"; *su* "Surangular"; *ar* "Articular"; *sy* Symphysis, or surface of junction with the right ramus.

Vertebrates, also, the mandible articulates with the skull, not directly, but by the intervention of a special bone known as the quadrate bone (*os quadratum*). This, in turn, may be joined directly with the temporal element of the skull, or may be separated from the latter by one or more bones, the whole constituting the "suspensorium" of the jaw. In Mammals, on the other hand, the mandible articulates directly with the temporal element of the skull, the quadrate taking no part in its articulation, but being converted into one of the small bones ("malleus") of the internal ear.

As regards the *limbs* of Vertebrates, whilst many differences exist which will be afterwards noticed, there is a general agreement in the parts of which they are composed. As a rule, each pair of limbs is joined to the trunk by means of a series of bones which also correspond to one another in general

structure. The fore-limbs, often called the "pectoral" limbs, are united with the trunk by means of a bony or cartilaginous arch, which is called the "pectoral" or "scapular" arch; whilst the hind-limbs (or "pelvic limbs") are similarly connected with the trunk by means of the "pelvic arch." In giving a general description of the parts which compose the limbs and their supporting arches, it will be best to take the case of a Mammal, and the departures from this type will then be readily recognised.

The pectoral or scapular arch consists usually of three bones, the "scapula" or shoulder-blade, the "coracoid," and the "clavicle" or collar-bone; but in the great majority of the Mammals, the coracoid is anchylosed with the scapula, of which it forms a mere process. The scapula or shoulder-blade (fig. 312, *s*) is usually placed outside the ribs, and it forms, either alone or in conjunction with the coracoidal element of the shoulder-girdle, the cavity with which the upper arm is articulated. The coracoid, though rarely existing as a distinct bone in the Mammals, plays a very important part in other Vertebrates, as we shall see hereafter. The clavicles are often wanting or rudimentary, and they are the least essential elements of the scapular arch. The fore-limb proper consists, firstly, of a single bone which forms the upper arm (or "brachium"), and which is known as the *humerus* (*h*). This articulates above with the shoulder-girdle, and is followed below by the fore-arm (or "antibrachium"), which consists of two bones called the *radius* and *ulna*. Of these the *radius* is chiefly concerned with carrying the hand (or "manus"). The radius and ulna are followed by the bones of the wrist, which are usually composed of several bones, and constitute what is called the *carpus* (*d*). These support the bones of the root of the hand, which vary in number, but are always more or less cylindrical in shape. They constitute what is called the *metacarpus*. The

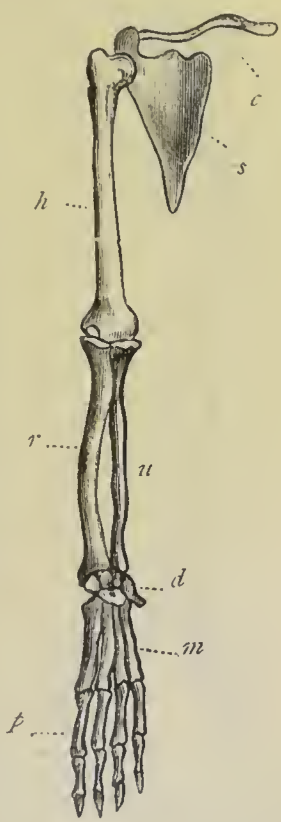

Fig. 312.—Pectoral limb (arm) of Chimpanzee (after Owen). *c* Clavicle; *s* Scapula or shoulder-blade; *h* Humerus; *r* Radius; *u* Ulna; *d* Bones of the wrist, or carpus; *m* Metacarpus; *p* Phalanges of the fingers.

bones of the metacarpus carry the digits, which also vary in number, but are composed each of from two to three cylindrical bones, which are known as the *phalanges* (*p*).

Homologous parts are, as a rule, readily recognisable in the hind-limb. The pelvic arch, by which the hind-limb is united with the trunk, consists of three pieces—the *ilium*, *ischium*, and *pubes*—which are usually anchylosed together, and form conjointly what is known as the *innominate bone* (fig. 313, *i*). In most Mammals, the two innominate bones unite in front by ligamentous or cartilaginous union, and they constitute, with the sacrum, what is known as the *pelvis*. The hind-limb proper consists of the following parts :—1. The thigh-bone or *femur*, corresponding with the humerus in the fore-limb. 2. The bones of the shank (or "crus"), corresponding with the radius and ulna of the fore-limb, and known as the *tibia* and *fibula*. Of these, the tibia is mainly or altogether concerned in carrying the foot (or "pes"), and it is thus shown to correspond to the radius, whilst the fibula corresponds to the ulna. 3. The small bones of the ankle, known as the *tarsus*, and varying in number in different cases. 4. A variable number of cylindrical bones (normally five), which are called the *metatarsus*, and which correspond to the metacarpus. 5. Lastly, the metatarsus carries the digits, which consist of from two to three small bones or *phalanges*, as in the fore-limb.

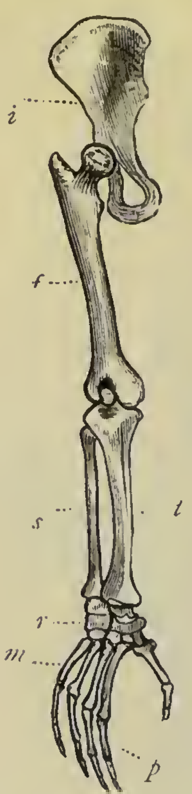

Fig. 313. — Pelvic limb (hind-limb) of Chimpanzee (after Owen). *i* Innominate bone; *f* Femur or thigh-bone; *t* Tibia; *s* Fibula; *r* Tarsus; *m* Metatarsus; *p* Phalanges of the toes.

The *digestive system* of Vertebrates will be spoken of at greater length hereafter; but a brief sketch may be given here of the general phenomena of digestion. All Vertebrate animals are provided with a mouth for the reception of food, and in the great majority of cases the mouth is furnished with *teeth*, which are used sometimes merely to hold the prey, but more commonly to cut and bruise the food, and thus render it capable of digestion. The food is also generally subjected in the mouth to the action of "salivary" glands (wanting in Fishes), the secretion of which serves not only to moisten the food, and thus mechanically assist deglutition, but also to render soluble the starchy elements of the food. The food is

next swallowed, or, in other words, is transferred from the mouth to the stomach, this being effected by a complicated arrangement of muscles, whereby the food is forced down the gullet (*œsophagus*) to the proper digestive cavity or stomach. In the stomach (fig. 314, *s*) the food is subjected to two sets of actions; it is mechanically triturated and ground down by the constant contractions of the muscular walls of the stomach; and it is subjected to the chemical action of a special fluid secreted by the stomach, and called the "gastric juice." This fluid has the power of reducing albuminoid substances to a soluble form, and by its action the food is ultimately reduced to a thick acid fluid, called the "chyme." Leaving the stomach by its lower aperture (the *pylorus*), the chyme passes into the intestine, the first portion of which is divided into several sections, but is collectively known as the "small intestine." Here the chyme is subjected to the action of three other digestive fluids: the *bile*, secreted by a special organ, the liver; the *pancreatic juice*, secreted by another gland, the pancreas; and the *intestinal juice*, secreted by certain glands situated in the mucous membrane of the intestine itself. The result of the whole process is that the "chyme" is ultimately converted into a white, alkaline, milky fluid, which is called "chyle." The indigestible portions of the food pass from the small intestine into a tube of larger dimensions, called the "large intestine." Such portions of the food as are still soluble, and capable of being employed in nutrition, are here taken up into the blood, the useless remainder being ultimately expelled by an anal aperture. The last portion of the large intestine is usually less convoluted than the rest, and is called the "rectum."

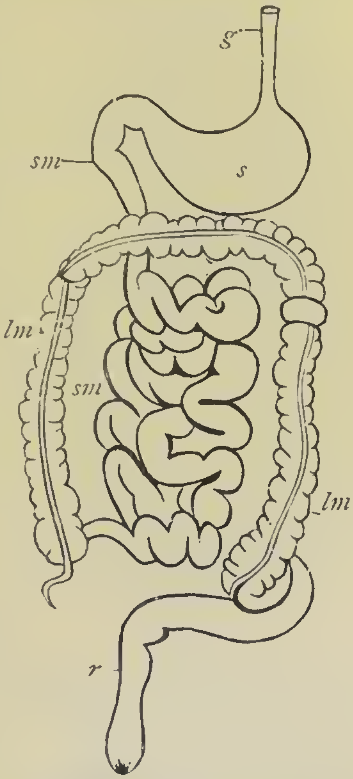

Fig. 314.—Diagram of the digestive system of a Mammal. *g* Gullet; *s* Stomach; *sm* Small intestine; *lm* Large intestine; *r* Rectum, terminating in the aperture of the anus.

The fluid and originally soluble portions of the food, and the chyle which is formed in the process of digestion, are taken

into the blood, the losses of which they serve to repair. Part of the nutritive materials of the food is taken up directly by the blood-vessels, and is conveyed by the "vena portæ" to the liver, whence it ultimately reaches the great veins which go to the heart. The greater part, however, of the liquefied food, constituting the chyle, is taken up, not by the blood-vessels, but by a special set of tubes, which form a network in the walls of the intestine, and are known as the "lacteals." In these vessels, and in certain glands which are developed upon them, the chyle undergoes still further elaboration, and is made more similar in composition to the blood itself. All the lacteal vessels ultimately unite into one or more large vessels which open into one of the veins, so that all the chyle is thus finally added to the mass of the circulating blood.

The *blood*, then, or nutrient fluid from which the tissues are built up, is formed in this way out of the materials which are taken into the alimentary canal as food. In all the Vertebrata, with exception of the Lancelet (*Amphioxus*) and of one or two oceanic fishes (*e.g.*, *Leptocephalus*), the blood is of a red colour when viewed in mass. This is due to the presence in it of an incredible number of microscopical bodies, which are known as the "blood-corpuscles," the fluid in which these float being itself colourless (fig. 315).

Fig. 315.—Blood-corpuscles of Vertebrata. *a* Red blood-discs of man; *b* Blood-discs of Goose; *c* Crocodile; *d* Frog; *e* Skate.

In all the *Vertebrata* the blood is distributed through the body by means of a system of closed tubes, which constitute the "blood-vessels"; and in all except the Lancelet, the means of propulsion are derived from a contractile muscular cavity or "heart," furnished with valvular apertures. In the most complete form of circulation, as seen in Birds and Mammals, the heart is essentially a double organ, composed of two halves, each of which consists of two cavities, an auricle and a ventricle. The right side of the heart is wholly concerned with the "lesser" or pulmonary circulation, whilst the left side is concerned with driving the blood to all parts of the body (systemic circulation). The modifications of the circulatory process will be noticed in speaking of the different classes of Vertebrates, but a brief sketch may be given here of the

circulation, in its most complete form, as in a Mammal. In such a case, the venous or impure blood, which has circulated through the body and has parted with its oxygen, is returned by the great veins to the right auricle. From the right auricle (fig. 316, *a*) the blood passes by a valvular aperture into the right ventricle (*v*), whence it is driven through the pulmonary artery to the lungs. The right side of the heart is therefore wholly respiratory in its function. Having been submitted to the action of the lungs, and having given off carbonic acid and taken up oxygen, the blood now becomes arterial, and is returned by the pulmonary veins to the left auricle (*a'*). From the left auricle the aerated blood passes through a valvular aperture into the left ventricle (*v'*), whence it is propelled to all parts of the body by means of a great systemic vessel, the "aorta." The left side of the heart is therefore wholly occupied in carrying out the "greater" or systemic circulation.

Fig. 316.—Diagram of the circulation of a Mammal. The venous system is marked black; the arterial system is left white. *a* Right auricle: *v* Right ventricle; *p* Pulmonary artery, carrying venous blood to the lungs; *pv* Pulmonary veins, carrying arterial blood from the lungs; *a'* Left auricle; *v'* Left ventricle; *b* Aorta, carrying arterial blood to the body; *c* Vena cava, carrying venous blood to the heart.

The purification of the blood is carried out in all Vertebrates by means of distinct respiratory organs, assisted to a greater or less extent by the skin. In the Fishes, and in the Amphibians to some extent, the process of respiration is carried on by means of *branchiæ* or gills—that is, by organs adapted for breathing air dissolved in water. These are therefore often spoken of as "Branchiate" Vertebrates; but the Amphibians always develop true lungs in the later stages of their existence. In the Reptiles, Birds, and Mammals, branchiæ are never developed, and the respiration is always carried on by means of true lungs—that is, by organs adapted for breathing air directly. These are therefore often spoken of as the "Abranchiate" Vertebrates.

The waste substances of the body—of which the most important are water, carbonic acid, and urea—are got rid of by the skin, lungs, and kidneys. Under ordinary circumstances, the lungs are mainly occupied with the excretion of carbonic

acid and watery vapour. The skin chiefly gets rid of superfluous moisture, but can also in many animals excrete carbonic acid as well. The kidneys are present in almost all Vertebrate animals, and their function is mainly to excrete water and the nitrogenous substance known as urea. In the majority of cases the fluid excreted by the kidneys is conveyed to the exterior by means of two tubes known as the ureters, which empty themselves into a common receptacle, the urinary bladder. In some cases, however, the ureters open along with the termination of the alimentary canal.

The nervous system of Vertebrate animals usually exhibits a well-marked division into two parts—the cerebro-spinal system, and the sympathetic system. The cerebro-spinal system of nerves constitutes the great mass of the nervous system of Vertebrates, and usually exhibits a well-marked separation into spinal cord (*myelon*) and brain (*encephalon*). The proportion borne by the brain to the spinal cord differs much in different cases; and in the Lancelet a brain can hardly be said to be present at all. As already said, the brain and spinal cord are always completely shut off from the visceral cavity, and they are placed upon the dorsal surface of the body. The nerves given off from the cerebro-spinal axis are symmetrically disposed on the two sides of the body, and they are mainly concerned with the functions of "animal" life—that is to say, with sensation and locomotion. The sympathetic system of nerves is unsymmetrically disposed to a greater or less extent, and presides mainly over the functions of "organic" or "vegetative" life, being chiefly concerned with regulating the functions of digestion and respiration, and the circulation of the blood. In its most fully developed form it consists of a double gangliated cord placed in the visceral cavity on the under surface of the spine, and of a series of nervous ganglia, united by nervous cords, and scattered chiefly over the great viscera of the thorax and abdomen.

The organs of the senses are well developed in the *Vertebrata*, and those appropriated to the senses of *sight*, *hearing*, *smell*, and *taste* are protected within bony cavities of the head. The perfection of the senses differs much in different cases, but they are probably never wholly wanting in any Vertebrate animal. There are cases in which vision must be of the most rudimentary character; but even in these cases it is probable that there is a perception of light, even if there is no power of distinguishing objects. The only cases in which it would appear that vision is really altogether absent, are those of animals placed under the wholly abnormal condition of spending their exist-

ence in darkness (such as the *Proteus anguinus* of the caves of Illyria). Smell, hearing, and taste are probably rarely, if ever, altogether absent in Vertebrates; though in many cases their organs are very rudimentary. Touch, or "tactile sensibility," is usually possessed to a greater or less degree by the entire surface of the body; but the sense of touch is generally localised in certain particular parts, such as the appendages of the mouth, the lips, the tongue, or the digits.

In all *Vertebrata* without exception reproduction is carried on by means of the sexes, and in all (except in some of the *Serranidæ* among the Fishes) the sexes are in different individuals. No Vertebrate animal possesses the power of reproducing itself by fission or gemmation; and in no case are composite organisms or colonies produced. Most of the Vertebrates are *oviparous*—that is to say, the *ova* are expelled from the body of the parent either before or very shortly after impregnation. In other cases, the eggs are retained within the body of the parent until the young are hatched, but no direct connection is formed between the fœtus and the mother, and in these cases the animals are said to be *ovo-viviparous*. In other cases, again, not only is the egg hatched within the parent, but the embryo is retained within the body of the mother, from whom it receives nourishment by indirect vascular connection, until its development has been carried out to a greater or less extent; and these animals are said to be *viviparous*.

Many Vertebrate animals possess an *exoskeleton*, formed by a hardening of one or other layer of the integument. The integument is composed of two layers—an external non-vascular "epidermis," and a deeper vascular "dermis"—and the exoskeleton may be formed by the deposition of horny matter, or of salts of lime, in either or in both of these. The epidermal exoskeleton is always horny, and, when present, is generally in the form of hairs (*Mammalia*), feathers (Birds), scales (Serpents and many Lizards), or plates (Chelonians). The horny sheaths of the jaws in Birds and some Reptiles, the outer covering of the horns in some Mammals, the hoofs, claws, and nails of *Mammalia*, are likewise epidermic. The dermal exoskeleton may be either horny or bony; and good examples of it are to be found in the scales of Fishes, the bony scutes of the Crocodiles, and the armour-plates of the Armadillos.

Divisions of the Vertebrata.—The sub-kingdom *Vertebrata* is divided into the five great classes of the Fishes (*Pisces*), Amphibians (*Amphibia*), Reptiles (*Reptilia*), Birds (*Aves*), and Mammals (*Mammalia*). So far there is perfect unanimity;

but when it is inquired into what larger sections the Vertebrata may be divided there is much difference of opinion. Here, the divisions proposed by Professor Huxley will be adopted; but it is necessary that those employed by other writers should be mentioned and explained.

One of the commonest methods of classifying the *Vertebrata* is to divide them into the two primary sections of the *Branchiata* and *Abranchiata*. Of these, the Branchiate section includes the Fishes and Amphibians, and is characterised by the fact that the animal is always provided at some period of its life with branchiæ or gills. The Abranchiate section includes the Reptiles, Birds, and Mammals, and is characterised by the fact that the animal is never provided at any time of its life with gills. Additional characters of the Branchiate Vertebrates are, that the embryo is not furnished with the structures known as the *amnion* and *allantois*. Hence the Branchiate Vertebrates are often spoken of as the *Anamniota* and as the *Anallantoidea*. In the Abranchiate Vertebrates, on the other hand, the embryo is always provided with an amnion and allantois, and hence this section is spoken of as the *Amniota* or as the *Allantoidea*.*

By Professor Owen the *Vertebrata* are divided into the two primary sections of the *Hæmatocrya* and the *Hæmatotherma*, the characters of the blood-system being taken as the distinctive feature. The *Hæmatocrya* or Cold-blooded Vertebrates comprise the Fishes, Amphibia, and Reptiles, and are characterised by their cold blood and imperfect circulation. The *Hæmatotherma* or Warm-blooded Vertebrates comprise the Birds and the Mammals, and are characterised by their hot blood, four-chambered heart, and complete separation of the pulmonary and systemic circulations. The chief objection to this division lies in the separation which is effected between the Reptiles and the Birds, two classes which are certainly very nearly allied to one another.

* The *amnion* is a membranous sac, containing a fluid—the liquor amnii—and completely enveloping the embryo. It constitutes one of the so-called "fœtal membranes," and is thrown off at birth. The *allantois* is an embryonic structure, which is developed out of the middle or "vascular" layer of the blastoderm. It appears at first as a solid, pear-shaped, cellular mass, arising from the under part of the body of the embryo. In the process of development, the allantois increases largely in size, and becomes converted into a vesicle which envelops the embryo in part or wholly. It is abundantly supplied with blood, and is the organ whereby the blood of the fœtus is aerated. The part of the allantois which is external to the body of the embryo is cast off at birth; but the portion which is within the body is retained, and is converted into the urinary bladder.

By Professor Huxley the *Vertebrata* are divided into the following three primary sections:—

I. ICHTHYOPSIDA.—This section comprises the Fishes and the Amphibians, and is characterised by the presence at some period of life of gills or branchiæ, the absence of an amnion, the absence or rudimentary condition of the allantois, and the possession of nucleated red blood-corpuscles.

II. SAUROPSIDA.—This section comprises the Birds and the Reptiles, and is characterised by the constant absence of gills, the possession of an amnion and allantois, the articulation of the skull with the vertebral column by a single occipital condyle; the composition of each ramus of the lower jaw of several pieces, and the articulation of the lower jaw with the skull by the intervention of an "os quadratum"; and, lastly, the possession of nucleated red blood-corpuscles.

III. MAMMALIA.—This section includes the single class of the Mammals, and agrees with the preceding in never possessing gills, and in having an amnion and allantois. The *Mammalia*, however, differ from the *Sauropsida* in the fact that the skull articulates with the vertebral column by two occipital condyles; each ramus of the lower jaw is simple, composed of a single piece, and the lower jaw is united with the temporal (squamosal) element of the skull, and is not articulated to a quadrate bone. There are special glands — the mammary glands — for the nourishment of the young for a longer or shorter period after birth, and the red blood-corpuscles are non-nucleated.

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DIVISION I.—ICHTHYOPSIDA.

CHAPTER XLVII.

CLASS I.—PISCES.

THE first class of the *Vertebrata* is that of the Fishes (*Pisces*), which may be broadly defined as including *Vertebrate animals which are provided with gills throughout the whole of life; the heart, when present, consists* (except in *Dipnoi*) *of a single auricle and a single ventricle; the blood is cold; the limbs, when present, are in the form of fins, or expansions of the integument; and there is neither an amnion nor allantois in the embryo, unless the latter is represented by the urinary bladder.*

In form, fishes are adapted for rapid locomotion in water, the shape of the body being such as to give rise to the least possible friction in swimming. To this end also, as well as for purposes of defence, the body is usually covered with a coating of scales developed in the inferior or dermal layer of the skin; whereas the epidermis is represented only by the slimy mucus covering the exterior of the animal. The more important modifications in the form of these dermal scales are as follows: I. *Cycloid* scales (fig. 317, *a*), consisting of thin, flexible, horny or bony scales, circular or elliptical in shape, and having a more or less completely smooth outline. These are the scales which are characteristic of the most of the ordinary Bony Fishes. II. *Ctenoid* scales (fig.

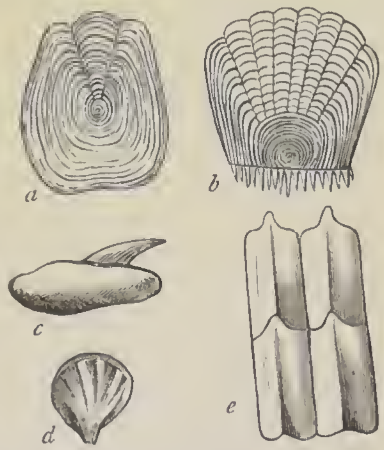

Fig. 317.—Scales of different fishes. *a* Cycloid scale (Pike); *b* Ctenoid scale (Perch); *c* Placoid scale (Thornback); *d* Placoid scale of *Rhina*; *e* Ganoid scales (*Palæoniscus*).

317, *b*), also consisting of thin horny plates, but having their posterior margins fringed with spines, or cut into comb-like projections. III. *Ganoid* scales, composed of an inferior layer of bone, covered by a superficial layer of hard polished enamel (the so-called "ganoine"). These scales (fig. 317, *e*) are usually much larger and thicker than the ordinary scales, and though they are often articulated to one another by special processes, they only rarely overlap. IV. *Placoid* scales, consisting of detached bony or dentinal grains, tubercles, or plates, of which the later are not uncommonly armed with spines (fig. 317, *c* and *d*).

In many fishes there is also to be observed a line of peculiar scales, forming what is called the "lateral line" (fig. 318). Each of the scales in this line is perforated by a tube leading down to a longitudinal canal which runs along the side of the

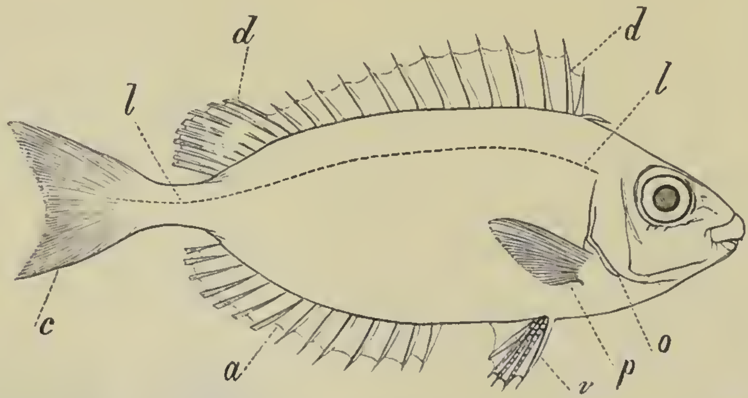

Fig. 318.—Side-view of a Teleostean Fish (*Teuthis nebulosa*) showing the "lateral line" (*l*); *d* Front portion of the dorsal fin, with hard rays; *d'* Hinder portion of the dorsal fin, with soft rays; *c* Caudal fin; *a* Anal fin; *v* One of the ventral fins; *p* One of the pectoral fins; *o* Operculum. (After Günther.)

body, and is continued into the head. Connected with the lateral line is a recurrent branch of the pneumogastric nerve (sometimes chiefly derived from the 5th nerve), termed the "lateral nerve." This runs superficially underneath the lateral line, or is placed deeply between the lateral muscles, or there may be both a deep and a superficial branch. The canals of the lateral lines have usually been believed to have the function of secreting mucus, and high authorities still adhere to this view. The system is, however, richly supplied with nerves, which terminate in peculiar sense-organs, so that its function is probably to a large extent sensory.

As regards their true osseous system or endoskeleton, fishes vary very widely. In the Lancelet there can hardly be said to

be any skeleton, the spinal cord being simply supported by the gelatinous notochord, which persists throughout life. In others the skeleton remains permanently cartilaginous; in others it is partially cartilaginous and partially ossified; and, lastly, in most modern fishes it is entirely ossified, or converted into bone. Taking a Bony Fish (fig. 319) as in this respect a typical example of the class, the following are the chief points in the osteology of a fish which require notice:—

The *vertebral column* in a Bony Fish consists of vertebræ which are hollow at both ends, or biconcave, and are technically said to be "amphicœlous." The cup-like margins of the vertebral bodies are united by ligaments, and the cavities formed between contiguous vertebræ are filled with the gelatinous remains of the notochord. This elastic gelatinous substance acts as a kind of ball-and-socket joint between the bodies of the vertebræ, thus giving the whole spine the extreme mobility which is requisite for animals living in a watery medium. The ossification of the vertebræ is often much more imperfect than the above, but in no case except that of the Bony Pike (*Lepidosteus*) is ossification carried to a greater extent than this. In this fish, however, the vertebral column is composed of "opisthocœlous" vertebræ—that is, of vertebræ the bodies of which are concave behind and convex in front. The entire spinal column is divisible into not more than two distinct regions, an *abdominal* and a *caudal region*. The abdominal vertebræ possess a superior or neural arch (through which passes the spinal cord), a superior spinous process (neural spine), and two transverse processes to which the ribs are usually attached. The caudal vertebræ (fig. 319) have no marked transverse processes; but, in addition to the neural arches and spines, they give off an inferior or *hæmal* arch below the body of the vertebræ, and the hæmal arches carry inferior spinous processes (hæmal spines).

The *ribs* of a Bony Fish are attached to the transverse processes, or to the bodies of the abdominal vertebræ, in the form of slender curved bones which articulate with no more than one vertebra each, and that only at a single point. Unlike the ribs of the higher Vertebrates, the ribs do not enclose a thoracic cavity, but are simply embedded in the muscles which bound the abdomen. Usually each rib gives off a spine-like bone, which is directed backwards amongst the muscles. Inferiorly the extremities of the ribs are free, or are rarely united to dermal ossifications in the middle line of the abdomen; but there is never any breast-bone or *sternum* properly so called.

The only remaining bones connected with the skeleton of

the trunk are the so-called *interspinous bones*, or "interneural" and "interhæmal" bones (fig. 319). These form a series of dagger-shaped bones, plunged in the middle line of the body between the great lateral muscles which make up the greater part of the body of a fish. The internal ends or points of the interspinous bones are attached by ligament to the points of the neural and hæmal spines of the vertebræ; whilst to their outer ends are articulated the "rays" of the so-called "median" fins, which will be hereafter described. As a rule, there is only one interspinous bone to each neural or hæmal spine, but in the Flat-fishes (Sole, Turbot, &c.) there are two.

Besides the fins which represent the limbs (pectoral and ventral fins), fishes possess other fins placed in the middle line of the body, and all of these alike are supported by bony spines or "rays," which are of two kinds, termed respectively "spinous rays" and "soft rays." The "spinous rays" (fig. 319, *k*) are

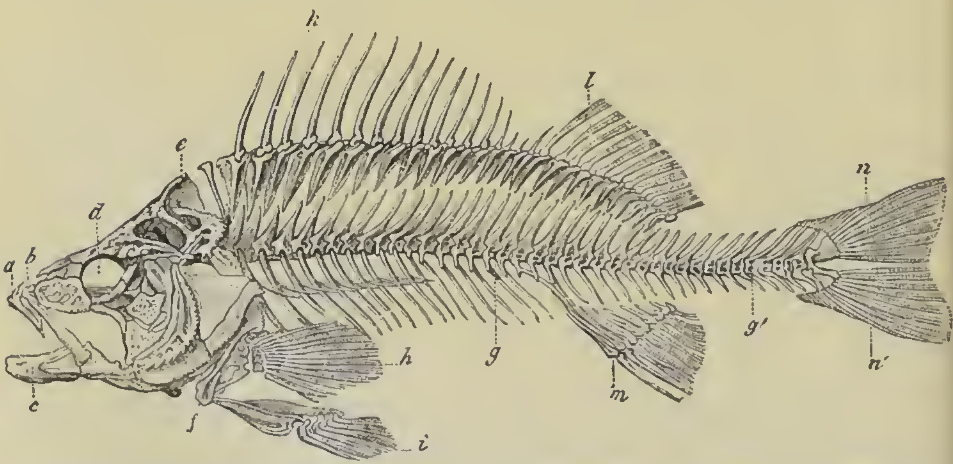

Fig. 319.—Skeleton of the common Perch (*Perca fluviatilis*). *a* Præmaxilla; *b* Maxilla; *c* Mandible; *d* Orbit; *e* Supra-occipital bone; *f* Præoperculum; *g g′* Vertebral column; *h* One of the pectoral fins; *i* One of the ventral fins; *k* First dorsal fin, with spinous rays; *l* Second dorsal fin, with soft rays; *m* Anal fin; *n n′* Caudal fin.

simple bony spines, apparently composed of a single piece each, but really consisting of two halves firmly united along the middle line. The "soft rays" are composed of several slender spines proceeding from a common base, and all divided transversely into numerous short pieces. The soft rays occur in many fishes in different fins, but they are invariably found in the caudal fin or tail (fig. 319, *n*). The rays of the median fins, whatever their character may be, always articulate by a hinge-joint with the heads of the interspinous bones.

The *skull* of the Bony Fishes is an extremely complicated

structure, and it is impossible to enter into its composition here. The only portions of the skull which require special mention are the bones which form the gill-cover or operculum, and the hyoid bone with its appendages. For reasons connected with the respiratory process in fishes, as will be afterwards seen, there generally exists between the head and the scapular arch a great cavity or gap on each side, within which are contained the branchiæ. The cavity thus formed opens externally on each side of the neck by a single vertical fissure or "gill-slit," closed by a broad flap, called the "gill-cover" or "operculum," and by a membrane termed the "branchiostegal membrane."

The gill-cover (fig. 320) is composed of a chain of broad flat bones, termed the opercular bones. Of these, the innermost, or most anterior articulates with the suspensorium of the jaw, and is called the "præ-oper-

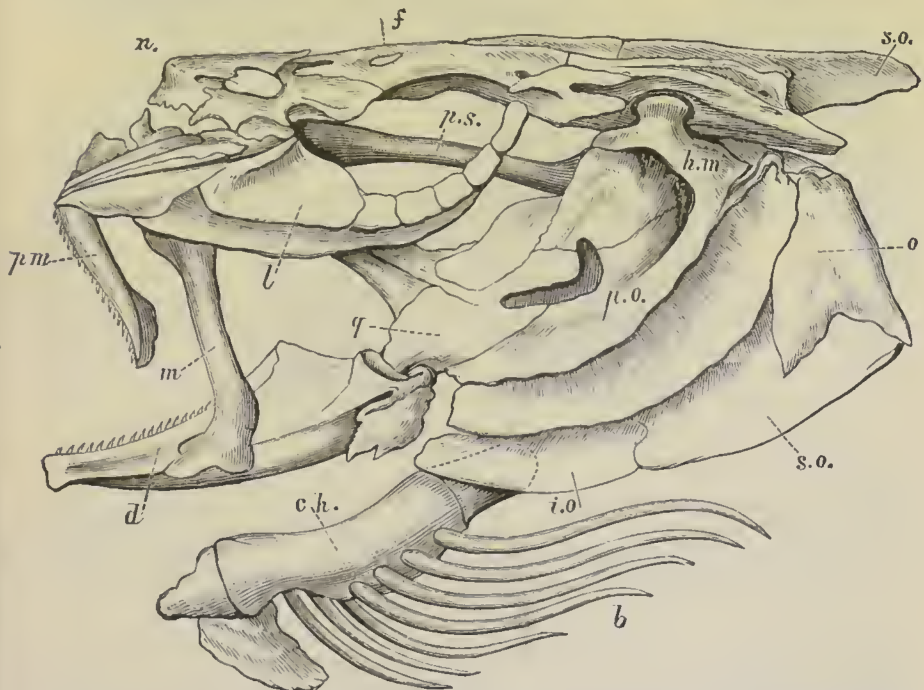

Fig. 320.—Side-view of the skull of the Cod (*Gadus morrhua*). *po* Præoperculum; *o* Operculum; *so* Sub-operculum; *io* Interoperculum; *ch* Ceratohyal, carrying the branchiostegal rays (*b*) behind, and articulating superiorly with the epihyal and inferiorly with the basihyal (below the basihyal is the urohyal); *d* Dentary portion of the mandible; *pm* Præmaxilla; *m* Maxilla, without teeth; *l* Lachrymal; *n* Nasal; *f* Frontal; *so* Supra-occipital; *q* Quadrate; *hm* Hyomandibular; *ps* Parasphenoid. (After Owen.)

culum"; the next is a large bone called the "operculum" proper; and the remaining two bones, called respectively the "sub-operculum" and "interoperculum," form, with the operculum proper, the edge of the gill-cover. These various bones are united together by membrane, and they form col-

lectively a kind of movable door, by means of which the branchial chamber can be alternately opened and shut. Besides the gill-cover, however, the branchial chamber is closed by a membrane called the "branchiostegal membrane," which is attached to the os hyoides. The membrane is supported and spread out by a number of slender curved spines, which are attached to the lateral branches of the hyoid bone, act very much as the ribs of an umbrella, and are known as the "branchiostegal rays" (fig. 320, *b*).

The hyoid arch of fishes is attached to the inner surface of the hyomandibular bones by means of two slender curved bones, which form the top segment of the hyoid, and are termed the "stylohyal" bones (figs. 321, 322, *sh*). Each stylohyal articulates inferiorly with a triangular bone known

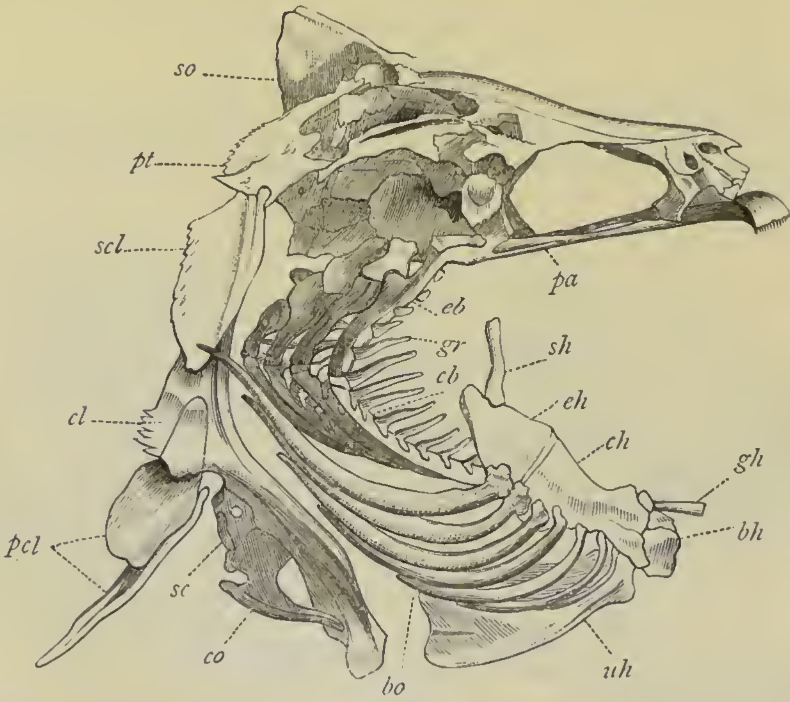

Fig. 321.—Bisected skull of the Perch, with the hyoid arch, branchial arches, and pectoral arch on one side (after Cuvier). *sh* Stylohyal; *eh* Epihyal; *ch* Ceratohyal: *bh* Basihyal; *gh* Glossohyal; *uh* Urohyal; *bo* Branchiostegal rays; *cb* Ceratobranchial; *eb* Epibranchial; *gr* One of the "gill-rakers" of the first branchial arch; *pa* Parasphenoid; *so* Supra-occipital; *pt* Post-temporal; *scl* Supra-clavicle; *cl* Clavicle; *pcl* The two pieces of the post-clavicle; *sc* Scapula; *co* Coracoid.

as the "epihyal" (*eh*), and this in turn is joined below with the "ceratohyal" (*ch*), which is the longest bone in the hyoid arch on each side. The central portion of the hyoid arch is formed by a pair of "basihyal" bones (*bh*) on each side, these being small polyhedral bones which become connected in the middle line with their fellows on the opposite side. From the point of union of the basihyals there extends *forwards* into the tongue a slender azygous "glossohyal" bone (*gh*), which is joined behind to the first of the so-called "basibranchial" bones (fig. 322, *ba*). The glossohyal usually bears a row of teeth, which project into the floor of the mouth. Extending *backwards* from the point of union of the basihyals, and below the line of basibranchial bones, is a vertically-compressed bone which is known as the "urohyal" (fig. 321, *uh*). The urohyal is of importance, as

it is connected behind by fibrous tissue with the point of union of the right and left pectoral arches, and it thus helps to form the isthmus which separates the two sets of branchiæ. Lastly, from the posterior margin of the epihyal and ceratohyal bones on each side, arise the slender curved bony spines which have been previously spoken of as "branchiostegal rays" (figs. 321, 322, *bo*). The function of these is to support the "branchiostegal membrane," by which the gill-slit is closed below. The number of "branchiostegal rays" varies greatly in the Bony Fishes, but is usually seven on each side (twelve in the *Salmonidæ*).

Behind the hyoid arch in Fishes are placed the post-hyoidean visceral arches, which are termed "branchial arches," as some of them always carry

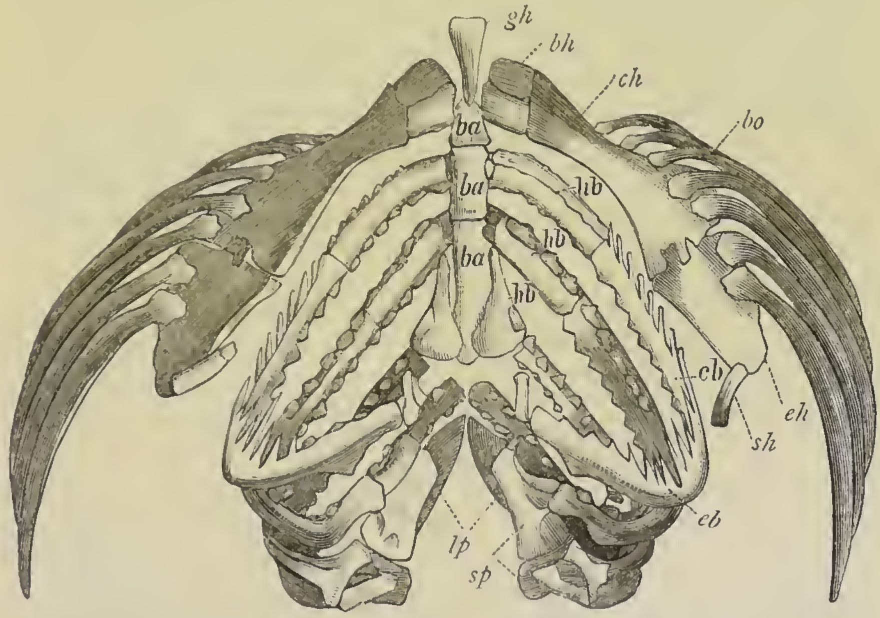

Fig. 322.—The hyoid and branchial arches of both sides of the Perch, removed from the skull, and viewed from above. (After Cuvier.) *sh* Stylohyal; *eh* Epihyal; *ch* Ceratohyal; *bh* Basihyal; *gh* Glossohyal; *bo* Branchiostegal rays; *ba* Basibranchial bones, separating the two sets of branchial arches; *hb* Hypobranchials (the 3d hypobranchial belongs to the 3d and 4th branchial arches); *cb* Ceratobranchial bone; *eb* Epibranchial bone; *sp* Superior pharyngeal (pharyngobranchial) bones; *lp* The incomplete 5th branchial arches, constituting the so-called inferior pharyngeal bones.

branchiæ on their outer sides. Seven branchial arches on each side is the greatest number known; but the arrangement which is most typical is that seen in the ordinary Bony Fishes, in which there are four complete branchial arches and a fifth incomplete one on each side. In a typical Bony Fish, such as the Perch or Cod, the branchial arches (fig. 322) consist of the following parts:—

(1.) Placed in the middle line of the floor of the mouth, and separating the two sets of branchial arches, is a row of small bones continued backwards from the glossohyal, and known as the "basibranchials" (*ba*).

(2.) From this basibranchial isthmus the branchial arches are continued upwards in the walls of the pharynx, to be attached to the roof of the mouth behind. Their basal segments, by which they join the basibranchials, are the so-called "hypobranchial" bones (*hb*). There are, however, only

three hypobranchials, the 3d and 4th arches having one in common, while the 5th has none.

(3.) Attached to the preceding are the "ceratobranchial" bones (*ch*), which are the principal pieces of the branchial arches. In the 5th branchial arch, the ceratobranchials are the only pieces developed, and they bear no branchiæ. Their inner surfaces in this arch are furnished with teeth, and they are placed one on each side of the middle line of the throat, constituting the so-called "inferior pharyngeal bones."

(4.) United with the upper ends of the ceratobranchials, and forming with them a curved angle, are the "epibranchials" (*eb*).

(5.) The branchial arches are completed superiorly by short pieces known as "pharyngobranchial" bones (*sp*), which are connected by fibrous tissue with the under side of the skull. The pharyngobranchials of the 1st and 4th arches are often rudimentary, while those of the 2d and 3d arches commonly bear teeth, and, projecting inwards from the upper wall of the pharynx, are known as the "superior pharyngeal bones."

(6.) Lastly, the inner margins of the branchial arches carry one or two rows of small denticular pieces, the "gill-rakers" (fig. 321, *gr*). These form a sieve which strains the water as it passes through the branchial clefts. The postero-external face of each branchial arch is further marked with a "branchial groove," in which the branchial vessels are contained, and to the sides of which the branchial laminæ are attached.

The lower jaw or *mandible* in the Bony Fishes consists of two rami, united by a ligamentous symphysis in front. Each ramus consists of two principal pieces (dentary and articular), with sometimes other elements ("angular," "splenial," &c.) as

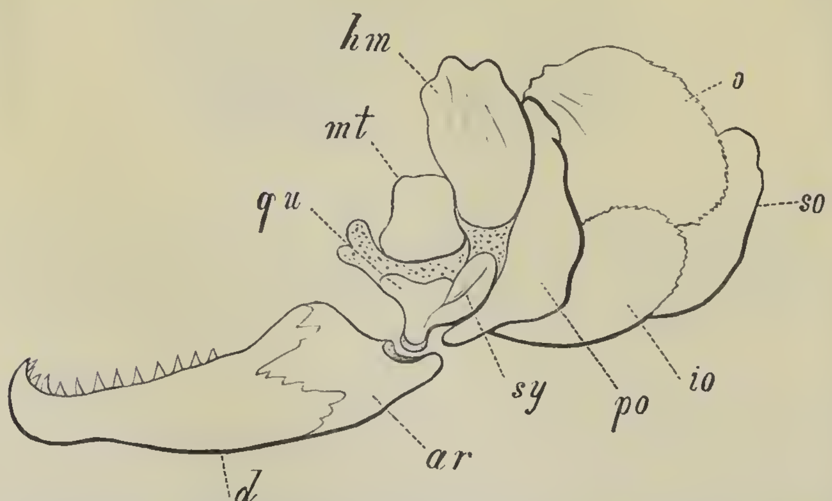

Fig. 323.—Mandible, mandibular suspensorium, and opercular bones of the Salmon (after Parker). *d* Dentary piece of mandible; *ar* Articular piece of mandible; *qu* Quadrate; *sy* Symplectic; *mt* Metapterygoid; *hm* Hyomandibular; *o* Operculum proper; *so* Sub-operculum; *io* Interoperculum; *po* Præoperculum.

well. The mandible is suspended from the skull by a series of bones which together constitute the "suspensorium," and which usually consist of the following (fig. 323):—

(1.) A "quadrate" bone (*qu*), which articulates directly with the mandibular condyle.

(2.) A small bone, connected with the postero-internal face of the quadrate, and known as the "symplectic" (*sy*).

(3.) A flat "metapterygoid" bone ("prætympanic" of Owen), placed above the quadrate, and united with it by cartilage.

(4.) A broad flat "hyomandibular" bone ("epitympanic" of Owen), which forms the uppermost segment of the suspensorium, and is articulated with the pterotic bone of the skull (*hm*). Posteriorly the operculum and præoperculum are connected with the hyomandibular, and the stylohyal bone is articulated to its inner surface. The hyomandibular bone, by its articulation with the skull, thus forms the hinge upon which swing the mandibular and hyoid arches, and the flap of the gill-cover.

The *limbs* of fishes depart considerably from the typical form exhibited in the higher Vertebrates. One or both pairs of limbs may be wanting, but when present the limbs are almost always in the form of *fins*—that is, of expansions of the in-

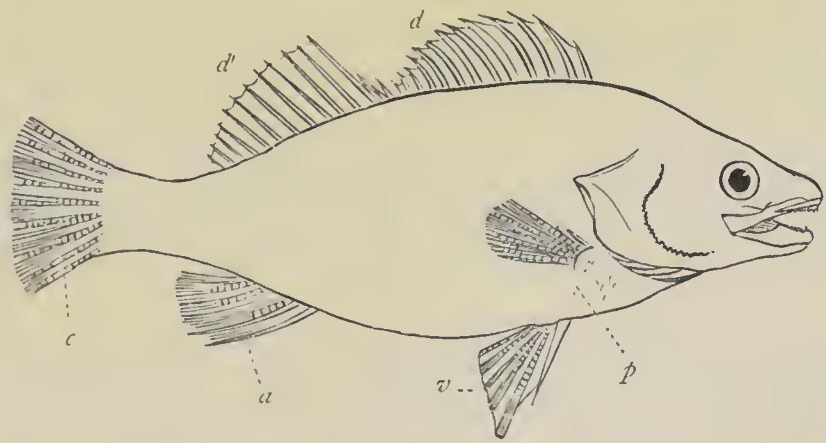

Fig. 324.—Outline of a fish, showing the paired and unpaired fins. *p* One of the pectoral fins; *v* One of the ventral fins; *d* First dorsal fin; *d'* Second dorsal fin; *a* Anal fin; *c* Caudal fin.

tegument strengthened by bony or cartilaginous fin-rays. The anterior limbs are known as the *pectoral* fins, and the posterior as the *ventral* fins; and they are at once distinguished from the so-called "median" fins by being always disposed in pairs, usually symmetrically. Hence they are often spoken of as the *paired* fins.

The pectoral limbs possess a well-developed pectoral arch,

which in Teleosteans is composed of several bones, and is articulated with the back of the skull, whereas in Elasmobranchs it is cartilaginous and has no connection with the cranium. The segments representing the upper arm and forearm are wanting, but carpal bones or cartilages are present, and these are followed by the "rays" of the fins proper, these representing the metacarpal bones, and phalanges. As regards size and other minor characters, the pectoral fins vary greatly. In the Flying Gurnard (*Dactylopterus*), and in the true Flying Fish (*Exocœtus*), the pectorals are enormously developed, and enable the fish to take extensive leaps out of the water.

Suspended from the back of the skull, and placed behind the branchial arches, are the pectoral arches in the ordinary Bony Fishes. In such a Fish as the Perch or Cod the pectoral arch (fig. 321) is composed of the following pieces:—

(1.) A bifid "post-temporal bone" ("supra-scapula" of Owen), by which the pectoral arch is joined to the supra-occipital and pterotic bones of the skull (*pt*).

(2.) This unites below with a second piece (*scl*), the "supra-clavicle" ("scapula" of Owen).

(3.) This, in turn, articulates inferiorly with a long curved "clavicle" ("coracoid" of Owen). The clavicles (*cl*) are the largest pieces of the pectoral arch, and they become connected in the middle line below, at the hinder end of the branchial isthmus.

(4.) Attached to the upper part of the clavicle is a two-jointed, backwardly-projecting "post-clavicle" (the "epicoracoid" of Owen, fig. 321, *pcl*).

(5.) Articulating with the hinder margin of the clavicle inferiorly are two short flat bones (*sc* and *co*), which represent respectively the "scapula" and "coracoid" (the "radius" and "ulna" of Owen).

(6.) The scapula and coracoid give origin to a series of short pieces, in two rows, which are believed to represent "carpals" and "metacarpals," and the latter bear the "fin-rays" of the fins.

The hind-limbs or "ventral fins" are wanting in many fishes, and they are less developed and less fixed in position than are the pectoral fins. In the ventral fins no representatives of the tarsus, tibia and fibula, or femur, are ever developed. The rays of the ventral fins—representing the metatarsus and the phalanges of the toes—unite directly with a pelvic arch, which is composed of two sub-triangular bones, united in the middle line and believed to represent the pubic bones. The imperfect pelvic arch, thus constituted, is never united to the vertebral column in any fish. In those fishes in which the ventral fins are "abdominal" in position (*i.e.*, placed near the hinder end of the body) the pelvic arch is suspended freely amongst the muscles. In those in which the ventral fins are "thoracic" or "jugular" (*i.e.*, placed beneath the pectoral fins, or on the

sides of the neck), the pelvic arch is attached to the point of junction of the clavicles, and is therefore wholly removed from its proper vertebra.

In addition to the pectoral and ventral fins—the homologues of the limbs—which may be wanting, fishes are furnished with certain other expansions of the integument, which are "median" in position, and must on no account be confounded with the true "paired" fins. These median fins are variable in number, and in some cases there is but a single fringe running round the posterior extremity of the body. In all cases, however, the median fins are "azygous"—that is to say, they occupy the middle line of the body, and are not symmetrically disposed in pairs. Most commonly, the median fins consist of one, two, or three expansions of the dorsal integument, called the "dorsal fins" (fig. 324, *d*, *d′*); one or two on the ventral surface near the anus—the "anal fins" (fig. 324, *a*); and a broad fin at the extremity of the vertebral column, called the "caudal fin" or tail (*c*). In all cases, the rays which support the median fins are articulated with the so-called interspinous bones, which have been previously described. Though called "median," from their position in the middle line of the body, and from their being unpaired, the median fins of fishes, as shown by Goodsir and Humphry, are truly to be regarded as formed by the coalescence of two lateral elements in the mesial plane of the body.

The caudal fin, or tail, of fishes is always set vertically at the extremity of the spine, so as to work from side to side, and it is the chief organ of progression in the fishes. In its vertical position, and in the possession of fin-rays, it differs altogether from the horizontal integumentary expansion which constitutes the tail of the *Cetacea* (Whales, &c.), and *Sirenia* (Dugong and Manatee). In the form of the tail, fishes exhibit some striking differences. In some of the Bony Fishes and Ganoids, the caudal extremity of the spine is not bent upwards, but divides the caudal fin-rays into two nearly equal portions, and the symmetrical tail-fin thus produced is said to be "diphycercal."

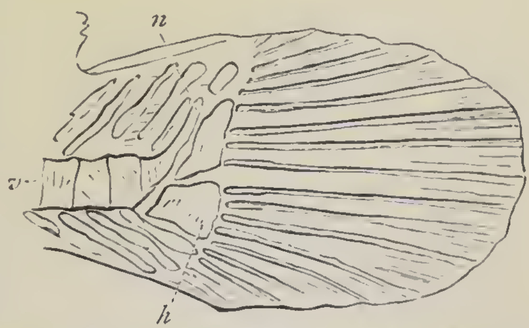

Fig. 325.—Tail of adult Flounder. (After A. Agassiz.) *v* Vertebral column; *n* Turned-up end of the notochord; *h* Hypural bones.

In the great majority of the Bony Fishes the tail-fin appears on inspection to be divided into two equal lobes, and it is then said to be "homocercal" (fig. 326, A). This apparent symmetry is due to the fact that the spinal column seems to terminate in the centre of a triangular bony mass ("hypural bone"), which is formed of co-ossified hæmal spines, and to the free edges of which the fin-rays are symmetrically attached (fig. 325, *h*). In reality, however, the unossified notochord is prolonged into the upper lobe of the tail; and as there is a much larger number of fin-rays below the bent-up notochord than above it, the tail is truly unsymmetrical in its fundamental structure. Lastly, in the *Elasmobranchii*, and most Ganoids, the tail is conspicuously unsymmetrical (fig. 326, B),

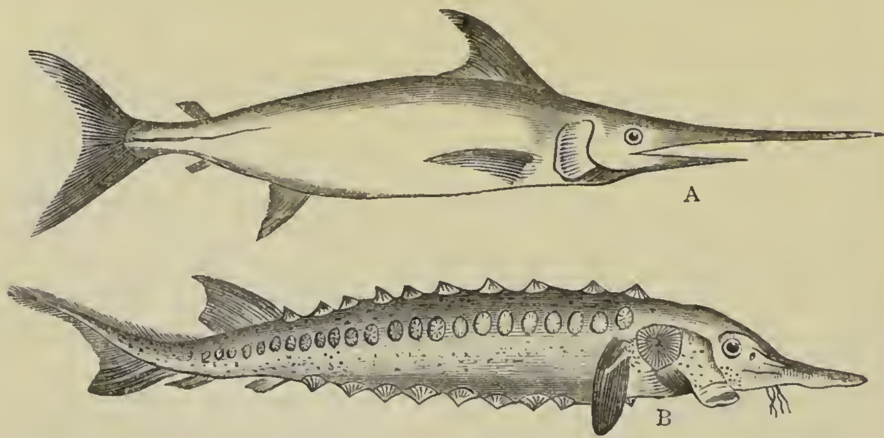

Fig. 326.—A, Sword-fish, showing homocercal tail; B, Sturgeon, showing the heterocercal form of tail.

and is then said to be "heterocercal." In these cases, the lower lobe of the tail is conspicuously larger than the upper, owing to the disproportionate development of the hæmal rays, and the spinal column is prolonged into the upper lobe of the tail.

In a recently published and important memoir, Professor A. Agassiz has shown that in *Pleuronectes* and various other living Bony Fishes, the tail of the early embryo is rounded, and is symmetrically developed at the hinder end of the straight notochord ("leptocardial stage"). Soon the chorda becomes arched upwards, and there appears the first trace of a separation of the tail-fin into two portions, only one of which is destined to remain permanently. The superior of these two divisions, when both have become fully marked out, surrounds the end of the upturned chorda (fig. 327, *a*), and it must be regarded as an embryonic structure, since it finally disappears. The inferior of the two divisions, on the other hand, is placed below the embryonic tail, and is ultimately developed into the permanent tail. At first the permanent caudal fin has the appearance of a distinct lobe, which looks like a second anal fin. In process of growth, however,

the embryonic caudal becomes thrown more and more upwards, and the rays of the permanent caudal acquire a fan-like arrangement. At the stage figured below (fig. 327) the tail is truly "heterocercal," and is wonderfully similar in appearance to the tail of many Palæozoic Fishes. Finally, how-

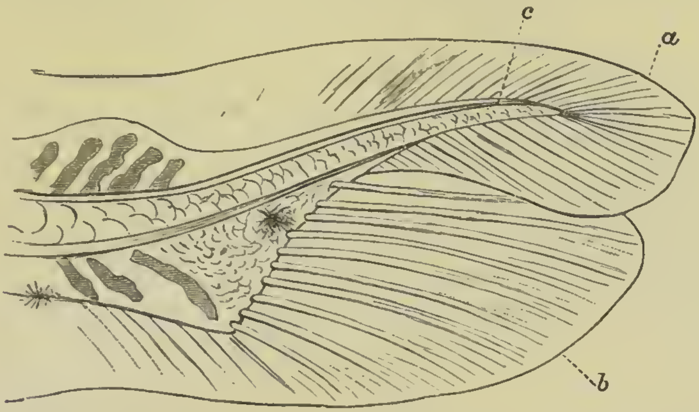

Fig 327.—Tail of young Flounder (*Pleuronectes*) in its heterocercal stage of development. *a* Embryonic caudal fin; *b* Permanent caudal fin, occupying an inferior position; *c* Bent-up end of the notochord. (After A. Agassiz.)

ever (fig. 325), the turned-up end of the notochord becomes replaced by the bony "urostyle"; the embryonic caudal diminishes in size and disappears; and the permanent caudal increases in size, and is gradually transformed from a ventral into a terminal appendage, the tail-fin thus assuming its permanent "homocercal" form. It would thus appear that the really earliest stage of the tail in the Bony Fishes and Elasmobranchs is the "leptocardial" stage, in which the tail is symmetrical and the notochord straight. This stage is in progress of growth superseded by the "heterocercal" condition, which subsists throughout life in the Elasmobranchs. Finally, the heterocercal tail of the young Bony Fish is in the adult succeeded by the permanent "homocercal" or "diphycercal" tail.

The process of *respiration* in all fishes is essentially aquatic, and is carried on by means of branchial plates or tufts developed upon the posterior visceral arches, which are persistent, and do not disappear at the close of embryonic life, as they do in other Vertebrates. In the Lancelet alone, respiration is effected partly by branchial filaments placed round the commencement of the pharynx, and partly by the pharynx itself, which is greatly enlarged, and has its walls perforated by a series of transverse ciliated fissures. The arrangement and structure of the branchiæ differ a good deal in the different orders of fishes, and these modifications will be noticed subsequently. In the meanwhile it will be sufficient to give a brief description of the organs of respiration in one of the Bony Fishes. In such a fish, the branchial apparatus is connected through the chain of basibranchial bones with the hyoid arch,

and is contained in two special chambers, situated one on each side of the neck. The branchiæ are carried upon the outer convex sides of what have been already described as the "branchial arches"; that is to say, upon a series of bony arches (figs. 321 and 322) which are connected with the basibranchial bones inferiorly, and are united above with the base of the skull. Between the branchial arches are the vertical fissures (branchial clefts), which allow the water to pass from the pharynx into the branchial chambers on each side. The postero-external face of each branchial arch is deeply grooved, and on each side of this groove is developed a row of elongated, pointed, cartilaginous "branchial laminæ," which are covered with a highly vascular mucous membrane. Each branchial arch thus carries, as a rule, two rows of branchial leaflets, though the fourth arch may have only a single row. As it circulates through the capillaries of the branchial laminæ, the venous blood is subjected to the action of the water holding oxygen in solution, and is thus arterialised. The water is constantly

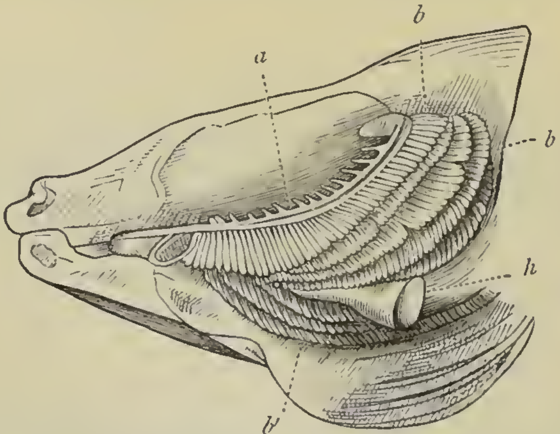

Fig. 328.—Gills and heart of the Perch, exposed by the removal of the gill-cover on the left side. *a* First of the four bony arches which carry the gills (*b b*); *b'* The lower edges of the gills on the right side; *h* Heart. (After Van der Hoeven.)

taken in at the mouth by a process analogous to swallowing, and is admitted to the branchiæ through the clefts in the walls of the pharynx. Having passed over the gills, the deoxygenated water is expelled by the "gill-slits," one of these being situated on each side of the neck. The entrance of foreign bodies into the branchial chambers is prevented by rows of bony processes ("gill-rakers") developed on the inner or concave sides of the branchial arches. Lastly, the gill-slit can be closed or opened by the to-and-fro movement of the "gill-cover" or operculum, and by the elevation or depression of

the "branchiostegal rays" with the "branchiostegal membrane" which these support.

The circulation through the branchial laminæ is as follows (fig. 329). The vessels which respectively carry the venous blood to the branchial laminæ and conduct the arterial blood away therefrom —viz., the "branchial artery" (*a*) and "branchial vein" (*c*)—run together in the groove on the outer side of the branchial arch, the vein lying nearest to the arch. The branchial artery sends a branch along each of the inner or opposed sides of the branchial laminæ, which break up into capillaries, and distribute the venous blood in the mucous membrane of the laminæ. After aeration the arterial blood is collected into two principal vessels (*d d*) which run along the outer edges of the branchial laminæ, and these open into the main branchial vein (*c*) lying in the branchial groove of the arch. The so-called "pseudobranchia," which is situated in the inner surface of the gill-cover in many Bony Fishes, receives only arterial blood, and has in these no respiratory function in the adult.

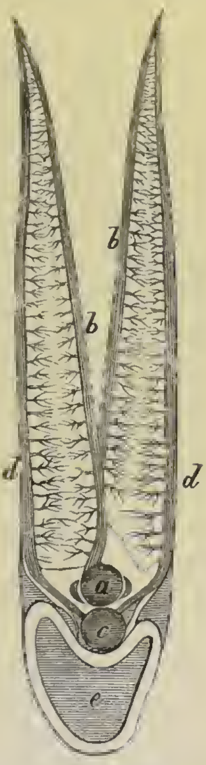

Fig. 329. — Diagram of a pair of branchial laminæ in a Bony Fish. *e* The branchial arch transversely divided, showing the external groove in which the great vessels run; *a* Branchial artery, giving off branches (*bb*) along the inner edges of the branchial laminæ; *c* Branchial vein, receiving branches (*dd*) from the outer edges of the branchial laminæ.

As regards the *circulatory system*, there are various modifications in different groups of Fishes, and it will be best to take an ordinary Bony Fish as presenting a typical condition as regards the heart and circulation (fig. 330). In such a fish the heart, as in Fishes generally, is purely respiratory, and is mainly concerned with driving the venous blood to the branchiæ. The heart is situated in a pericardial chamber which lies in front of the pectoral arch, and communicates posteriorly with the peritoneal cavity. The blood which has circulated through the body, and has thus become venous, is collected by the great veins, and is ultimately discharged into a common dilatation (the "sinus venosus") which lies just behind the heart. The sinus venosus opens into a large thin-walled "auricle" (fig. 330, *au*) which is the first cavity of the heart proper, and which projects on both sides of the ventricle. The auricle by its contraction drives the blood into a conical, thick-walled, muscular ventricle (*v*), from which arises the great "branchial artery," or the great vessel which distributes the venous blood to the gills. The base of the branchial artery is dilated into a pyriform muscular chamber known as the "arterial bulb" (fig. 330, *ab*), which

looks as if it were a third cavity of the heart. In the so-called *Palæichthyes* (Ganoids, Elasmobranchs, and Dipnoous Fishes) the bulbus arteriosus is of a comparatively complex structure, and, its base being rhythmically contractile, it really acts as a forward continuation of the heart. The branchial artery in front of the arterial bulb gives off on each side the great vessels (*ba*) which carry the blood to the gills. In most of the Bony Fishes there are four of these divisions of the branchial artery on each side, corresponding to the four functional branchial arches. The oxygenated blood returning from the gills is collected into the "branchial veins," which correspond in number to the branches of the branchial artery. The branchial veins do not return, however, to the heart, but unite below the spine to form the great systemic vessel—the "subvertebral aorta" or "descending aorta" (fig. 330, *sa*). This is continued backwards below the vertebral column, and its branches distribute the arterial blood to the tissues generally. The blood, thus rendered venous, is collected into the veins and is again returned to the heart, thus completing the circulation.

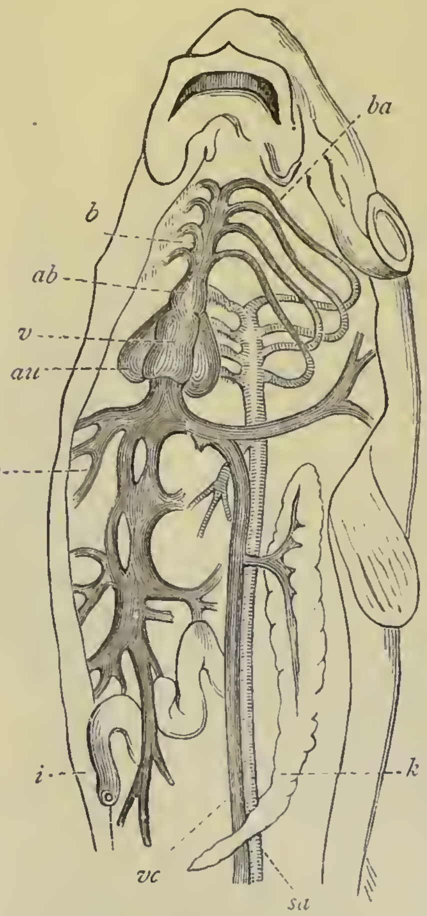

Fig. 330.—Diagram of the circulatory system in a Fish, the vessels containing venous blood being longitudinally shaded, and those containing arterial blood being cross-shaded. *vc* Vena cava; *vp* Vena portæ; *au* Auricle; *v* Ventricle; *ab* Bulbus arteriosus; *b* Branchial artery; *ba* One of the divisions of the branchial artery going to the gills, from which proceeds one of the corresponding branchial veins, by the union of which the subvertebral aorta (*sa*) is formed; *i* Intestine; *k* Kidney.

It will be seen from the above that the essential peculiarity of the heart is that it is purely venous, and is concerned only with driving the impure blood to the breathing organs; whereas the arterialised blood returned from the gills is propelled through the systemic vessels without being sent back to the heart. The

single contraction of the heart is thus sufficient to drive the blood through both the branchial and the systemic circulations, some assistance being afforded by the contractions of the voluntary muscles. In some fishes also (as in the Eel), the return of blood to the heart is assisted by a rhythmically contractile dilatation of the caudal vein.

In *Amphioxus* alone there is no heart, the principal vessels being contractile, and acting as a heart. In the *Dipnoi* the auricle may be incompletely divided into a right and left half (as in *Lepidosiren*), or the ventricle may show a similar imperfect division (as in *Ceratodus*). The blood-discs of Fishes are oval and nucleated (fig. 315, *e*), and the blood is red in all except *Amphioxus* and the oceanic *Leptocephalus* and its allies.

As regards the *digestive system*, the mouth in Fishes is usually capacious, and generally is furnished with teeth, which in the Bony Fishes are not only developed upon the mandible, præmaxillæ, and maxillæ (the latter often edentulous), but may also be produced upon other bones which enter into the composition of the buccal cavity (such as the palatines, pterygoids, vomer, branchial arches, and glossohyal bone). The œsophagus (fig. 331, *œ*) is usually short and wide, passing almost without a visible external boundary into the stomach. The latter is usually bent and U-shaped, the first or "cardiac" division (*cd*) being wide; while the second or "pyloric" division is much narrower. In other cases, the cardiac division of the stomach is prolonged backwards as a long blind sac, and the cardiac and pyloric openings are placed close together. In the angle formed by the two divisions of the bent stomach usually lies the ductless and vascular spleen. The stomach is succeeded by the small intestine, into the commencement of which the bile-duct (fig. 331, *dl*) opens. In ordinary Bony Fishes the commencement of the duodenum is marked by the presence of a variable number (from 1 to 200) of blind tubular appendages (fig. 331, *pc*), which are known as the "pyloric cæca," and which exercise some digestive function. These are wanting in Elasmobranchs, in which the small intestine is excessively short, and they are also absent in many other fishes. The small intestine terminates in a short large intestine, which either opens directly upon the exterior, just in front of the anal fin, as in most Bony Fishes, or debouches into a dilated chamber or "cloaca," which receives also the urinary and reproductive ducts (as in Elasmobranchs). In Elasmobranchs, Ganoids, and *Dipnoi*, the absorbing surface of the large intestine is increased by a "spiral valve," in the form of a spiral reduplicature of the mucous membrane which winds like a

screw in close turns round the intestinal tube. The liver in fishes is usually large, soft, and oily, and a gall-bladder is generally present. In *Amphioxus* the liver is represented by a sac-like diverticulum of the alimentary tube. A distinct pancreas (fig. 331, *pa*) is found in Elasmobranchs and many other fishes,

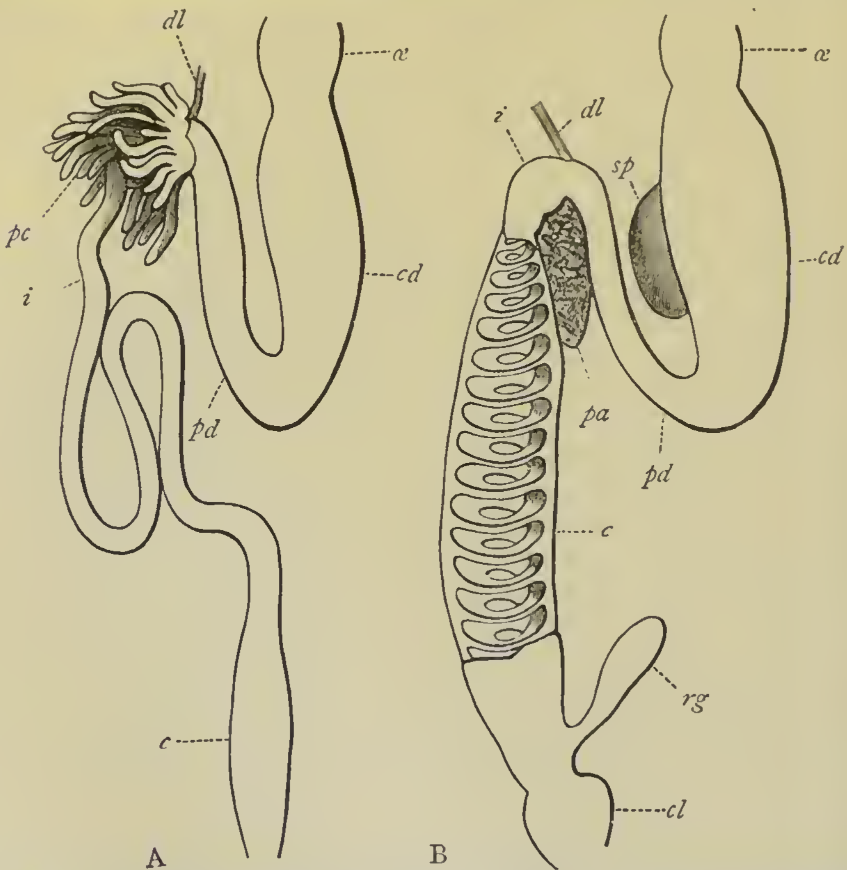

Fig. 331.—Diagrammatic sketches of the alimentary canal of a Bony Fish (A), and an Elasmobranch (B). *æ* Œsophagus; *cd* Cardiac division of the stomach; *pd* Pyloric division of the stomach; *dl* Bile-duct; *i* Small intestine (duodenum); *c* Large intestine; *pc* Pyloric cæca; *rg* Rectal gland; *cl* Cloaca; *pa* Pancreas; *sp* Spleen. The large intestine in B is supposed to be partly laid open so as to show the spiral valve in its interior.

but it is wanting in many Teleosteans. Lastly, in Elasmobranchs there is appended to the large intestine, near its termination, a vascular and cæcal glandular pouch (the "rectal gland," fig. 331, *rg*).

The *kidneys* of Fishes are usually of considerable size, and form two elongated organs which are situated beneath the spinal column, and may extend along the whole length of the abdominal cavity. The ureters often join into a common duct, upon which a urinary bladder may be developed. In

Bony Fishes the urinary opening is placed in general behind the anus, either in common with the generative aperture, or just posterior to the latter.

In many fishes there is developed the curious sac-like organ which is known as the "swim-bladder" or "air-bladder." This structure is an unpaired, or rarely paired, sac, containing gas, and situated underneath the vertebral column and above the alimentary canal. It is often of considerable size, and usually is unilocular, but it may be variously subdivided by septa, or it may give off more or less complicated cæca (fig. 332).

Fig. 332.—Swim-bladder of *Corvina trispinosa*, showing appended cæca.

In *Lepidosiren* and some Ganoids the air-bladder is double, and in these cases it is more or less cellular or spongy. In all the *Dipnoi* and Ganoids also, as in many Teleostean Fishes, the swim-bladder communicates with the gullet by means of a duct (*ductus pneumaticus*). On the other hand, in most Teleosteans the air-bladder has the form of a closed ductless sac. No air-bladder is developed in the Marsipobranch and Elasmobranch fishes, and this organ is also wanting in certain Bony Fishes (*e.g.*, the Flat-fishes). The swim-bladder has been generally regarded as the homologue of the lungs of the air-breathing Vertebrates, though in most cases it has no respiratory function. The gas which it contains is secreted from the blood by the lining membrane of the swim-bladder, which is vascular, and is often furnished with *retia mirabilia*, and it is not derived from the atmosphere (except in the case of the *Dipnoi*). In most fresh-water fishes the gaseous contents of the organ are mostly made up of nitrogen, but oxygen is the predominating ingredient in the case of the sea-fishes. In an ordinary way it would seem that the functions of the air-bladder are purely hydrostatic, the fish having, by muscular action, the power of compressing the sac, and thus altering its specific gravity. On the other hand, among the *Dipnoi* the air-bladder discharges a true respiratory function.

The *nervous system* of Fishes is of a comparatively low type, the brain being smaller in proportion to the body than in any other class of Vertebrates. The olfactory lobes (fig. 333, *i*) are well marked, the cerebral lobes are small (*c*); and the optic

lobes (*b*) are exceptionally developed, and may exceed any of the other divisions of the brain in size. The cerebellum is relatively small, and is never divided into two lateral lobes. The eyes are rudimentary in *Amphioxus*, and in other cases may be hidden under the skin, as in the Hag-fishes and in the blind fishes of caves. The nasal sac is single, with a single unpaired external nostril, in the Marsipobranchs; but in all other fishes the nasal sac is double, with two nostrils. In the great majority of Fishes the nasal sacs are closed posteriorly, and do not communicate with the mouth; but in *Myxine* the single nasal sac opens behind upon the palate, and in the *Dipnoi* there are two posterior nostrils corresponding with the double structure of the nose. The auditory organ consists of the "labyrinth" only, and the auditory capsule may be largely or wholly enclosed in the cranial walls, or attached to the sides of the brain-case. There is no external ear, but in the Rays, a canal leading from the internal ear opens upon the surface by a minute aperture. In all other fishes there is no external aperture to the auditory organs. In many cases, however, the ear is brought into relation with the swim-bladder. Peculiar nervous organs of Fishes are the "electrical organs," which are developed in the Electric Rays (*Torpedo*), the Electric Eel (*Gymnotus*), and in some other forms. The situation of these organs varies in different cases, but they are always largely supplied with nerves from the fifth pair and from the pneumogastric.

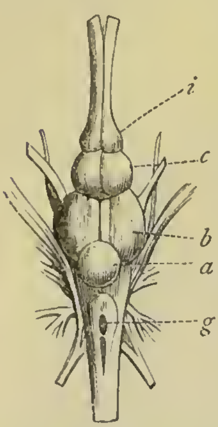

Fig. 333. — Brain of Perch, viewed from above (after Cuvier). *i* Olfactory lobes; *c* Cerebral lobes; *b* Optic lobes; *a* Cerebellum; *g* Fourth ventricle.

As regards their *reproductive organs*, Fishes have the sexes distinct, except in the *Serranidæ*, and in a few other cases. The reproductive organs of the two sexes are often very similar to one another, the ovaries being familiarly known as the "roe," while the testes are called the "soft roe" or "milt." The ovary is single in the Sharks and in a few other forms, but is usually paired, and there are two testes in all except the Marsipobranchs. In some cases the generative glands have no ducts, and the generative products are shed into the abdominal cavity, and reach the exterior by an "abdominal pore" placed behind the anus. This state of things occurs in the Marsipobranchs and in the females of the Salmon family. In the majority of the Bony Fishes the ovaries and testes have

ducts which are directly continuous with them, and which open on the surface by an aperture placed just behind the anus. In all the Ganoids (except *Lepidosteus*), and in the *Dipnoi*, the generative ducts are not direct prolongations of the generative glands, but have funnel-shaped internal apertures, into which the generative products are dehisced. The same is the case in the females of the Sharks and Rays. The Fishes are essentially oviparous, but some forms (Viviparous Blenny, Viviparous Dog-fishes, &c.) are ovo-viviparous; and in most of the latter the early stages of development are undergone by the embryo within a uterine enlargement of the oviduct. The ova (spawn) are generally fertilised by the semen after they have been shed into the water; but in some cases sexual congress takes place, and in the Sharks and Rays the males are furnished with "claspers" or external copulatory organs.

As regards their *distribution in space*, Fishes are essentially inhabitants of water, and most live exclusively in either the sea or fresh waters. A number of forms, however, have the power of living indifferently in either salt or fresh water, and migrate periodically from one to the other. *Ceratodus* appears to be able to come on land, breathing by means of its lung; and the African Lepidosiren (*Protopterus annectens*) can survive the drying up of the pools in which it lives by burying itself in the mud in a kind of chamber. Many fishes can live a considerable time out of water, either by reason of the narrowness of their gill-slits (as in Eels), or because there are special arrangements for keeping the gills moist.

As to their *distribution in time*, Fishes are the most ancient of Vertebrates. The oldest known remains of Fishes are found in the Silurian rocks, the still more ancient fossils known as "Conodonts," being almost certainly referable to the Invertebrates. The two most ancient groups of Fishes are the Ganoids and the Elasmobranchs, both of which are represented in the Silurian period. The *Dipnoi* are also a very ancient group, appearing for the first time in the Devonian. On the other hand, the Bony Fishes do not make their appearance till late on in the Secondary period (in the Chalk), and we have no knowledge of any fossil remains referable to the groups of the Marsipobranch and Pharyngobranch Fishes.

DIVISIONS OF FISHES.

CHAPTER XLVIII.

PHARYNGOBRANCHII AND MARSIPOBRANCHII.

Naturalists usually recognise at the present six principal groups or orders of Fishes—viz., the *Pharyngobranchii* (Lancelet), the *Marsipobranchii* (Lampreys and Hag-fishes), *Teleostei* (Bony Fishes), *Ganoidei* (Ganoid Fishes), *Elasmobranchii* (Sharks and Rays), and *Dipnoi* (Mud-fishes). The Lancelet (*Amphioxus*) is the sole representative of the order *Pharyngobranchii*, and its characters are so abnormal that it has been often regarded as the representative of a special division of Vertebrate Animals, to which has been given the names of *Acraniata* (from the want of a skull), or *Leptocardii* (from the fact that the heart is only represented by pulsating blood-sinuses). Again, the orders of the Ganoids, Elasmobranchs, and Dipnoous Fishes have many and important characters in common, and they have therefore been grouped together by Dr Günther into a special sub-class of *Pisces* under the name of *Palæichthyes*.

Order I. Pharyngobranchii (= *Cirrostomi*, Owen, and *Leptocardii*, Müller).—This order includes but a single fish, the anomalous *Amphioxus lanceolatus* or Lancelet (figs. 334, 335), the organisation of which differs in almost all important points from that of all the other members of the class. The order is defined by the following characters, most of which, as will be seen, are negative:—*No skull is present, nor lower jaw* (*mandible*), *nor limbs. The notochord is persistent; and there are no vertebral centra nor arches. No distinct brain nor auditory organs are present. In place of a distinct heart, pulsating dilatations are developed upon several of the great blood-vessels. The blood is pale. The mouth is in the form of a longi-*

tudinal fissure, surrounded by filaments or cirri. The walls of the pharynx are perforated by numerous clefts or fissures, the sides of which are ciliated, the whole exercising a respiratory function.

The Lancelet is a singular little fish, from one to two inches in length, which is found burrowing in sandbanks, in various seas, but especially in the Mediterranean. The body (fig. 334) is semi-transparent, destitute of an exoskeleton, and

Fig. 334.—Pharyngobranchii. The Lancelet (*Amphioxus lanceolatus*), enlarged.

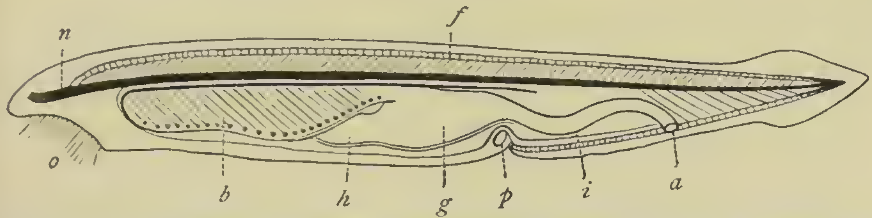

Fig. 335.—The Lancelet (*Amphioxus lanceolatus*), enlarged to twice its natural size. *o* Mouth; *b* Pharyngeal sac; *g* Stomach; *h* Diverticulum representing the liver; *i* Intestine; *a* Anus; *n* Notochord; *f* Rudiments of fin-rays; *p* Abdominal pore.

lanceolate in shape, and is provided with a narrow membranous border, of the nature of a median fin, which runs along the whole of the dorsal and part of the ventral surface, and expands at the tail to form a lancet-shaped caudal fin. No true paired fins, representing the anterior and posterior limbs, are present. The mouth is a longitudinal fissure, situated at the front of the head, and destitute of jaws. It is surrounded by a cartilaginous ring, composed of many pieces, which give off prolongations, so as to form a number of ciliated cartilaginous filaments or "cirri" on each side of the mouth. (Hence the name of *Cirrostomi*, proposed by Professor Owen for the order.) The throat is provided on each side with vascular lamellæ, which are believed by Owen to perform the function of free branchial filaments. The mouth leads into a dilated chamber (fig. 335, *b*), which represents the pharynx, and is termed the "pharyngeal" or "branchial sac." It is an elongated chamber, the walls of which are strengthened by numerous cartilaginous filaments, between which is a series of transverse slits or clefts, the whole covered by a richly-ciliated mucous membrane. This branchial dilatation has given rise to the name *Branchiostoma*, often applied

to the Lancelet. Posteriorly the branchial sac opens into an alimentary canal, to which is appended a long and capacious sac or cæcum (*h*), which is believed to represent the liver. The intestinal tube terminates posteriorly by a distinct anus (*a*), which is situated at the root of the tail a little to the left of the median line; and the intestinal mucous membrane is ciliated. Respiration is effected by the admission of water taken in by the mouth into the branchial sac, having previously passed over the free branchial filaments before mentioned. The water passes through the slits in the branchial sac, and thus gains access to the abdominal cavity, from which it escapes by means of an aperture with contractile margins situated a little in front of the anus, and called the "abdominal pore" (*p*). There is no distinct heart, and the circulation is entirely effected by means of rhythmically contractile dilatations which are developed upon several of the great blood-vessels. In other words, the heart retains its primitively tubular condition, and special contractile dilatations are developed upon other vessels (those carrying the blood to the pharynx). The blood itself is colourless. No kidneys have as yet been certainly identified, and there is no lymphatic system. There is no skeleton properly so called. In place of the vertebral column, and constituting the whole endoskeleton, is the semi-gelatinous cellular notochord (*n*), enclosed in a fibrous sheath, and giving off fibrous arches above and below. The notochord is, further, peculiar in this, that it is prolonged quite to the anterior end of the body, whereas in all other Vertebrates it stops short at the pituitary fossa. There is no cranium, and the spinal cord does not expand anteriorly to form a distinct cerebral mass. The brain, however, may be said to be represented, since the anterior portion of the nervous axis gives off nerves to a pair of rudimentary eyes, and another branch to a ciliated pit, believed to represent an olfactory organ. The generative organs (ovaria and testes) are not furnished with any efferent ducts (oviduct or vas deferens). The generative products, therefore, are shed into the abdominal cavity, and gain the external medium by the "abdominal pore."

ORDER II. MARSIPOBRANCHII (= *Cyclostomi*, Owen; and *Cyclostomata*, Müller).—This order includes the Lampreys (*Petromyzonidæ*) and the Hag-fishes (*Myxinidæ*), and is defined by the following characters:—*The body is cylindrical, worm-like, and destitute of limbs. The skull is cartilaginous, without cranial bones, and having no lower jaw* (*mandible*). *The notochord is persistent, and exhibits no vertebral segmentation. The*

heart consists of one auricle and one ventricle, but the branchial artery is not furnished with a bulbus arteriosus. The gills are sac-like and are not ciliated.

The type of piscine organisation displayed in the *Marsipobranchii* is of a very low grade, as indicated chiefly by the persistent notochord without vertebral centra, the absence of any traces of limbs, the absence of a mandible, and the structure of the gills.

Both the Lampreys and Hag-fishes (fig. 336) are vermiform,

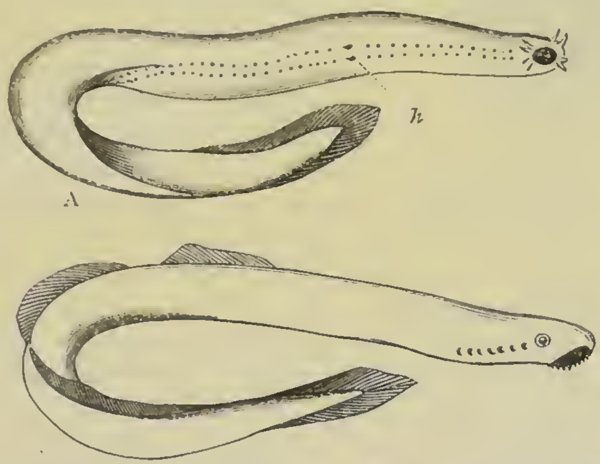

Fig. 336.—Morphology of Marsipobranchii. A, *Myxine glutinosa*, the Hag-fish, showing the sucker-like mouth, and the two ventral openings (*h*) by which the water escapes from the gills. B, The River Lamprey or Lampern (*Petromyzon fluviatilis*), showing the seven branchial apertures on the side of the neck.

eel-like fishes, which agree in the total want of scales, and in the absence of paired fins representing the limbs. The hinder end of the body is furnished with a median fin. The skeleton remains throughout life in an extremely imperfect condition, the chorda dorsalis being persistent, and not exhibiting segmentation into definite vertebræ. The neural arches are, however, represented by cartilaginous rudiments, and similar rudiments in the caudal region may represent hæmal arches. The skull is partly membranous and partly cartilaginous, and is not movable on the notochord.

The mouth is destitute of proper jaws, and is adapted for suction, fleshy lips being present in the Lampreys. Typically, the mouth has the form of a circular cup-like sucker, the inner surface of which is furnished with more or less numerous simple horny teeth developed in the buccal mucous membrane. At the bottom of the sucker is the aperture of the mouth, in which is a piston-like tongue, also armed with teeth

(fig. 337). In the Hag-fishes (*Myxine*) there is a single median fang-like tooth on the palate, and small comb-like teeth on the tongue. By the retraction of the piston-like tongue, the mouth can be used as a sucker, enabling the Marsipobranchs to attach themselves firmly to foreign objects.

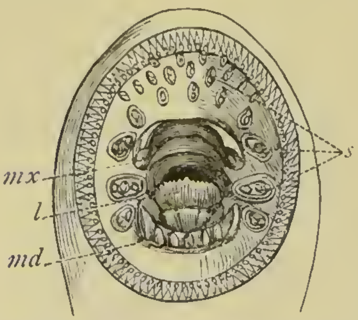

Fig. 337.—Mouth of Lamprey (*Petromyzon fluviatilis*). *mx* Maxillary tooth; *md* Mandibular tooth; *l* Lingual tooth; *s* Suctorial teeth. (After Günther.)

The form of the respiratory organs among the Marsipobranchs is quite peculiar. There are no branchial arches, as in Fishes generally, but the gills have the form of a number of flattened sac-like pouches situated on both sides of the œsophagus. In the Lampreys there are seven of these pouches on each side, and six on each side in the Hag-fishes; the arrangements for the admission of water to the branchial sacs and its expulsion from the same differing in important particulars. In the Hag-fishes (fig. 338), the water is admitted to the gullet through the unpaired nasal sac, which has the peculiarity that it opens into the throat behind. On each side of the gullet are six apertures through which the water is conducted by short canals into the six branchial sacs, the walls of which are richly vascular and thus officiate as breathing-organs. From each branchial sac the water is carried off by a special efferent duct, and the six efferent ducts on each side combine to form two common branchial ducts, which open on the ventral surface of the body, far behind the head, by a pair of approximated branchial pores (fig. 338, *p*). On the left side there is also a special canal (ductus œsophago-cutaneus) which leads from the gullet into the common branchial duct on each side.

In the Lampreys there are seven branchial pouches on each side, and these open laterally on the sides of the neck by a corresponding number of round apertures (fig. 336, B), each gill-sac thus having a separate efferent duct. The inner ducts of the branchial sacs of the two sides open into an unpaired common tube, which lies in the middle line beneath the gullet, and opens in front into the pharynx, while it terminates blindly behind. Though no branchial arches are present in the Lampreys, the gill-sacs are supported by a curious basket-like apparatus of cartilaginous rods.

There is no air-bladder in the Marsipobranchs. The heart is of the piscine type, consisting of an auricle and ventricle;

but the base of the branchial artery is not contractile, and there is no proper arterial bulb. The branches of the branchial artery correspond in number with the gill-pouches, and the branchial veins unite to form the sub-vertebral aorta.

The alimentary canal is simple and straight; the liver is not sac-like, but of its ordinary form, and the kidneys are distinct, but exhibit various embryonic features. The sexes are distinct, and the unpaired reproductive glands are ductless, the generative elements being shed into the abdomen, and escaping thence by a "generative pore" placed behind the anal aperture.

Lastly, the Marsipobranchs are peculiar in having a single median tubular nasal sac, with a correspondingly unpaired external nostril. In the Lampreys, as in Fishes generally, the nasal sac does not open behind into the mouth; but in the Myxinoids the nasal sac opens posteriorly upon the palate, and the water required for respiration is conducted into the gullet through the nasal cavity.

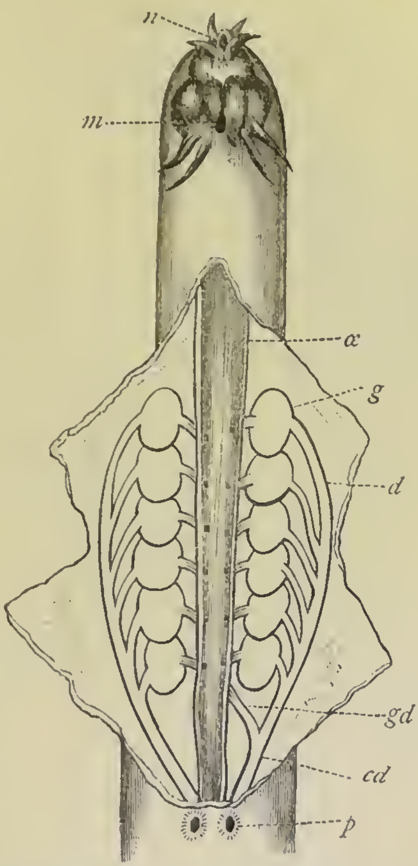

Fig. 338.—Anterior portion of the body of the Hag-fish (*Myxine glutinosa*), laid open on the ventral side to show the branchial sacs. *œ* The gullet laid open, showing on each side the six apertures by which the water is conducted to the corresponding branchial pouches (*g*); *d* One of the efferent ducts by which the water is conducted away from the branchial pouches; *cd* Common efferent duct on the left side, opening on the ventral surface by a branchial pore (*p*); *gd* Special canal (ductus œsophago-cutaneus) developed on the left side only, and leading from the gullet into the common branchial duct; *n* Unpaired nostril, with its "barbels"; *m* Opening of the mouth.

The Marsipobranchs live partly in the sea and partly in fresh water, some types frequenting salt water, but ascending rivers for the purpose of spawning. No certain remains of fishes belonging to this order have been discovered in a fossil condition.

The Marsipobranchs are divided into the two groups of the Lampreys (*Petromyzonidæ*) and the Hag-fishes (*Myxinidæ*). In the Lampreys, there is a complete circular sucking mouth, armed with numerous horny teeth

(fig. 337). Eyes are present, the single nostril is on the top of the head, and the nasal sac terminates blindly behind. The branchial pouches are seven in number on each side, opening on the side of the neck by as many distinct apertures. The great Sea-lamprey (*Petromyzon marinus*) quits the salt water in spring, and ascends rivers for the purpose of spawning. The common River-lamprey (*Petromyzon fluviatilis*) inhabits fresh water exclusively. The Lampreys feed principally on other fishes, to which they attach themselves by their suctorial mouths. The young Lamprey passes through a metamorphosis, being without eyes or teeth, and so unlike the adult that a special genus (*Ammocœtes*) was founded on their first discovery for their reception.

In the Hag-fishes (*Myxinidæ*) the mouth is without lips, and furnished with fleshy filaments or "barbels" (fig. 338, *m*). The single external nostril is placed at the front of the mouth, and is surrounded by four barbels (fig. 338, *n*); and the nasal sac opens behind upon the palate. There are six pairs of branchial sacs, and in *Myxine* the efferent ducts of these unite to form two efferent ducts which open by a pair of pores placed some distance behind the head upon the ventral surface. In the allied genus *Bdellostoma*, the gill-pouches have separate external apertures. The eyes are hidden beneath the skin, and are without function. The Hag-fishes have a single median fang upon the palate, and by means of this they bore their way into the abdominal cavity of other fishes, to which they first attach themselves by their suctorial mouth. The common Hag-fish, or "Glutinous Hag" (*Myxine glutinosa*) lives parasitically in this way in the interior of the Cod and other allied fishes. It derives its common name from the great quantity of slimy mucus which it has the power of secreting, and it is found in the North Atlantic generally.

CHAPTER XLIX.

TELEOSTEI.

ORDER III. TELEOSTEI.—This order includes the great majority of fishes in which there is a well-ossified endoskeleton, and it corresponds very nearly with Cuvier's division of the "Osseous Fishes." The *Teleostei* are defined as follows:—*The skeleton is usually well ossified; the cranium is provided with cranial bones, and a mandible is present; whilst the vertebral column almost always consists of more or less completely ossified amphicœlous vertebræ. The pectoral arch has a clavicle; and the two pairs of limbs, when present, are in the form of fins supported by rays. The gills are free, pectinated or tufted in shape; a bony gill-cover and branchiostegal rays being always developed. The branchial artery has its base developed into a bulbus arteriosus; but this is never rhythmically contractile, and is separated from the ventricle by no more than a single row of valves.*

The order *Teleostei* comprises almost all the common fishes; and it will be unnecessary to dilate upon their structure, as they were taken as the types of the class in giving a general description of the Fishes. It may be as well, however, to recapitulate very briefly some of the leading characters of the order.

The *skeleton*, instead of remaining throughout life more or less completely cartilaginous, is now always more or less thoroughly ossified. The notochord is not persistent, and the vertebral column, though sometimes cartilaginous, consists of a number of vertebræ. The bodies of the vertebræ are concave at both ends ("amphicœlous"), the doubly-conical cavities formed by the apposition of the centra of each successive pair of vertebræ being filled with the gelatinous remains of the notochord. The skull is always largely composed of distinct cranial bones, and a lower jaw or mandible is invariably present.

The anterior and posterior pairs of *limbs* are usually, but not always, present, and when developed they are always in the form of fins. The fins may be supported by "spinous" or "soft" rays, of which the former are simple undivided spines of bone, whilst the latter are divided transversely into a number of short transverse pieces, and also are broken up into a number of longitudinal rays proceeding from a common root. (The fishes with soft rays in their paired fins are said to be "malacopterygious"—those with spinous rays, "acanthopterygious.")

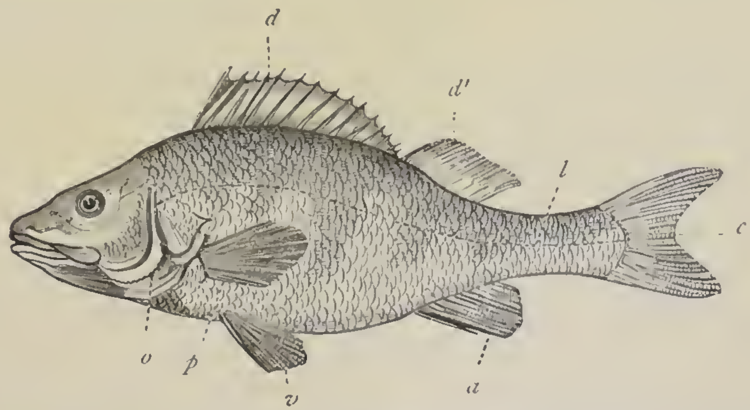

Fig. 339.—The Common Perch (*Perca fluviatilis*). *o* Gill-cover, with the gill-slit behind it; *p* One of the pectoral fins, the left; *v* The left ventral fin; *d* The first dorsal fin; *d'* The second dorsal fin; *c* The caudal fin or tail; *a* The anal fin; *l* Lateral line.

Besides the paired fins, representing the limbs, there is a variable number of unpaired or azygous integumentary expansions, which are known as the "median fins." When fully

developed (fig. 339), they consist of one, two, or three fins on the back—the "dorsal" fins; one or two on the ventral surface—the "anal" fins; and one clothing the posterior extremity of the body—the "caudal" fin. The tail-fin is equilobed and superficially quite symmetrical, and is therefore what is called "homocercal." As a general rule, however, the tail is in reality more or less "heterocercal," the termination of the notochord being prolonged upwards into its upper lobe, and the hæmal spines becoming fused to form one or more "hypural" bones, to which the fin-rays are symmetrically attached. The turned-up extremity of the notochord may in such cases remain unossified, or its sheath may become bony, and form a "urostyle," which becomes amalgamated with the upper edge of the "hypural" bones. In certain cases, the tail may be "diphycercal," the termination of the spinal column being placed in the centre of the caudal fin-rays.

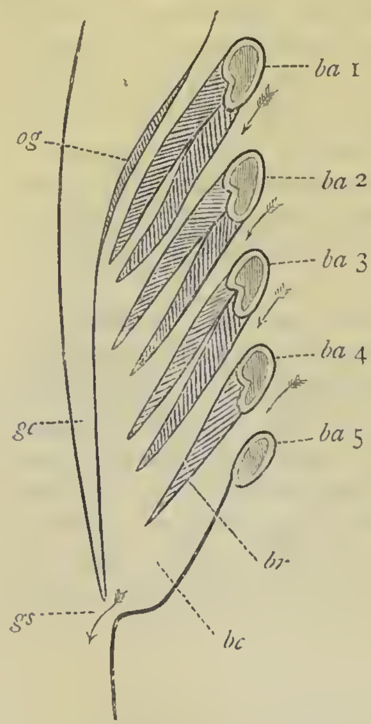

Fig. 340.—Diagram to show the arrangement of the gills in a Teleostean, as seen in a horizontal section of the branchial chamber on one side. *gc* Gill-cover; *gs* Gill-slit; *bc* Common branchial chamber; *ba* 1 to *ba* 4 The first four gill-bearing branchial arches, the first three having a double series of branchial laminæ, the fourth having only a single series; *ba* 5 The rudimentary fifth branchial arch ("inferior pharyngeal" bone), which carries no gills; *og* Pseudobranchia or "opercular gill," developed on the inner face of the gill-cover. The arrows show the passage of the water through the branchial fissures and out by the gill-slit.

The *heart* consists of two chambers, an auricle and a ventricle, and the branchial artery is furnished with a bulbus arteriosus. The arterial bulb, however, is not furnished with a special coat of striated muscular fibres, is not rhythmically contractile, and is separated from the ventricle by no more than a single row of valves.

The *respiratory organs* (fig. 340) consist of free, pectinated, or tufted branchiæ, situated in two branchial chambers, each of which communicates internally with the pharynx by a series of clefts, and opens externally on the side of the neck by a single aperture (or "gill-slit"), which is protected in front by a bony gill-cover (fig. 340, *gc*), and is also closed by a "branchiostegal membrane," supported upon "branchiostegal rays." The branchiæ are

attached to a series of bony branchial arches (generally five on each side, but only the anterior four bearing gills). All the four anterior arches may carry each a double row of branchial laminæ, but very commonly the fourth arch carries only a single row (fig. 340, *ba* 4), or may be destitute of a gill. The fifth branchial arch (*ba* 5) is without gills, and is reduced to its ceratobranchial piece, which carries teeth, and is termed the "inferior pharyngeal bone." A "pseudobranchia" (*og*) is generally developed on the inner face of the gill-cover, but it has no respiratory function.

The nasal sacs never communicate posteriorly with the cavity of the pharynx.

The exoskeleton usually has the form of overlapping horny scales of the cycloid or ctenoid character; but it is sometimes absent, sometimes composed of scattered plates of true bone, sometimes ganoid, and sometimes formed of shagreen-like bony spines.

The stomach is capacious; pyloric cæca are mostly present; the intestine has no spiral valve; and the rectum usually opens separate from and in front of the genital and urinary apertures. The air-bladder may or may not be present, and may or may not communicate with the gullet. The kidneys are well developed, and the ureters unite to open by a single median aperture placed in the middle line behind the anus. The ducts of the reproductive glands are directly continuous with the glands themselves, and open by a common aperture just in front of the single urinary opening. In the females of the *Salmonidæ* alone the ova are shed into the abdomen, and escape by an abdominal pore; while in the *Murænidæ* the reproductive glands of both sexes are without efferent ducts.

The Teleostean Fishes are by far the most abundant representatives of the class *Pisces* at the present day, but they are not known to have come into existence at all during the Palæozoic or the earlier portion of the Mesozoic period. The earliest undoubted remains of Teleostean fishes have been detected in rocks of Cretaceous age; but as many generic forms appear here, and as a number of these are closely allied to existing types, it may be safely concluded that the first appearance of the Teleosteans was at some period long anterior to the deposition of the Chalk.

The order of the *Teleostei* is divided into the following suborders:—

SUB-ORDER A. MALACOPTERI, Owen (= *Physostomi*, Müller).—This sub-order is defined by usually possessing a complete set of fins, supported by rays, all of which are "*soft*" or many-

jointed, with the occasional exception of the first rays in the dorsal and pectoral fins. A swim-bladder is generally present, and when present, always communicates with the œsophagus by means of a pneumatic duct. The skin is rarely naked, and is mostly furnished with cycloid scales; but in some cases ganoid plates are present.

In a number of Malacopterous Fishes—hence called *Apoda*—the ventral fins are wanting. Examples of such forms are the Eels (*Murænidæ*), in which the body is elongated and cylindrical, with a naked skin, or having minute scales deeply sunk in the skin. The common Eels (*Anguilla*) deposit their spawn in the sea, whither the adults migrate at certain seasons; and the young again make their way from the sea into rivers. The Conger-eels are exclusively marine in their habits. Allied to the true Eels is the great Electric Eel (*Gymnotus electricus*) of South America, which has the power of generating electricity by means of special organs.

In a second section of the *Malacopteri*—hence called *Abdominalia*—ventral fins are present, their position being "abdominal"—*i.e.*, placed far back towards the hinder end of the body. In this section are—(1) the *Clupeidæ* or Herrings, comprising the true Herrings (*Clupeus harenga*), the Sprat, Anchovy, &c. (2) The *Esocidæ*, or Pike family, typified by the common Pike (*Esox lucius*). (3) The *Cyprinidæ*, comprising the common Carp (*Cyprinus carpio*), the Roach and Chub (*Leuciscus rutilus* and *L. cephalus*), the Minnow (*Phoxinus lævis*), and many other familiar fishes. (4) The *Salmonidæ*, comprising the Salmon (*Salmo salar*), the common Trout (*S. fario*), the Sea-trout (*S. trutta*), the Smelt (*Osmerus eperlanus*), &c. (5) The *Siluridæ*, or "Sheat-fishes," in which the skin is scaleless, or furnished with bony scutes. In various forms of this family the first spine of the pectoral fins, as also often that of the dorsal fin, is in the form of a powerful pointed spine. A well-known example of this family is the great *Silurus glanis* of the fresh waters of Central and Eastern Europe. The common "Cat-fishes" of North America also belong to this family.

Sub-order B. Anacanthini.—This sub-order is distinguished by the fact that the fins are entirely supported by "soft" rays, and never possess "spiny" rays; whilst the ven-

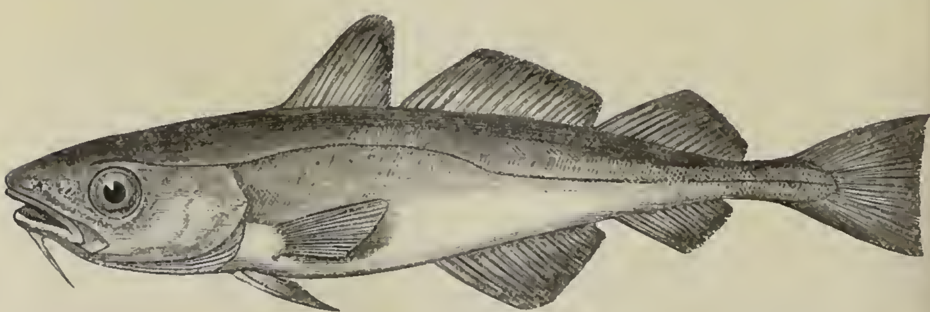

Fig. 341.—The Cod (*Gadus morrhua*).

tral fins are either wanting, or, if present, are placed under the throat, beneath or in advance of the pectorals, and supported by the pectoral arch. The swim-bladder may be wanting, but

when present it does not communicate with the œsophagus by a duct.

Leaving out of sight the small group represented by forms such as the Sand-eels (*Ammodytes*), in which ventral fins are wanting or rudimentary, the *Anacanthini* possess ventral fins which are "jugular" in position. These more typical Anacanthinous fishes (*Sub-brachiata*) comprise the two principal families of the *Gadidæ* and *Pleuronectidæ*. The members of the Cod family (*Gadidæ*) are very numerous, and they are almost entirely confined to the sea. Among the best-known types are the Cod (*Gadus morrhua*, fig. 341), the Haddock (*G. æglefinus*), the Whiting (*G. merlangus*), and the Coal-fish (*G. virens*).

In the group of the *Pleuronectidæ* or "Flat-fishes" are comprised the Plaice (*Pleuronectes platessa*), the Flounder (*P. flesus*), the Soles (*Solea*), the Turbot, Brill, &c. (*Rhombus*), the Halibut (*Hippoglossus vulgaris*), and many other allied forms, all of which are distinguished by a very curious modification in the form of the body. The body, namely, in all the Flat-fishes (fig. 342) is very much compressed from side to side, and is bordered

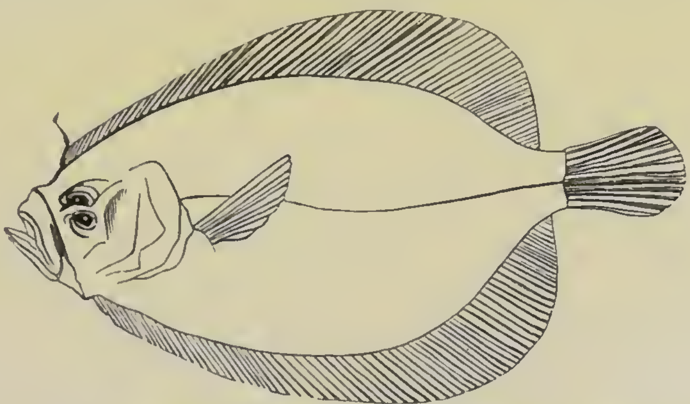

Fig. 342.—Pleuronectidæ (*Rhombus punctatus*). Natural size (after Gosse).

by long dorsal and anal fins. When young, the body is symmetrical, the eyes are bilaterally situated, and the animal swims in a vertical position. Soon, the habit of lying on one side (sometimes the right, but more commonly the left, side) is commenced, and then the eye upon the lower side is gradually translated to the upper side of the head; this translation being effected by an actual movement of the lower eye, by which it passes through the at that time soft tissues of the head, or by a partial twisting of the cranial bones. When adult, both eyes are situated upon one side of the head (fig. 342), and the fish now keeps this side uppermost, and is dark-coloured on this aspect; whilst the opposite side, on which it rests, is white. From this habit of the Flat-fishes of resting upon one flat surface, the sides are often looked upon as the dorsal and ventral surfaces of the body. This, however, is erroneous, as they are shown by the position of the paired fins to be truly the *lateral* surfaces of the body. The mouth has its two sides unequal, the pectorals are rarely of the same size, the ventrals look like a continuation of the anal fin, and the branchiostegal rays are six in number.

Sub-order C. Acanthopteri.—This sub-order is characterised by the fact that one or more of the first rays in the

fins are in the form of true, unjointed, inflexible, "spiny" rays. The exoskeleton consists, as a rule, of ctenoid scales. The ventral fins are generally beneath or in advance of the pectorals, and the duct of the swim-bladder is invariably obliterated.

The sub-order of the Acanthopterous fishes includes the two tribes of the *Pharyngognathi* and the *Acanthopteri veri*. In the former of these the inferior pharyngeal bones become anchylosed so as to form a single bone, which is usually armed with teeth. The scales may be of the ctenoid or cycloid type. The principal family included under the tribe of the *Pharyngognathi* is that of the "Wrasses" (*Labridæ*), in which the scales are of the cycloid character. Many forms belonging to this group are known, living in shallow water in temperate and tropical seas.

In the tribe of the *Acanthopteri veri*, the inferior pharyngeal bones remain distinct, and are not anchylosed with one another. In this very extensive group are comprised a number of families, of which the following are the most important :—(1) The Perch family (*Percidæ*), comprising the common Perch (*Perca fluviatilis*), the "Bass" (*Labrax*), the Sticklebacks (*Gasterosteus*), &c. The members of the Perch family are sometimes marine, sometimes fresh-water in habit; their scales are of the ctenoid type; and they commonly have the edge of the operculum and præoperculum variously armed with spines. (2) The Mullet family (*Mugilidæ*). (3) The Sea-breams (*Sparidæ*). (4) The Mackerel family (*Scomberidæ*), comprising the common Mackerels (*Scomber*), the Tunny (*Thynnus thynnus*) and "Bonito" (*T. pelamys*), and the Sucking-fishes (*Echeneis*). (5) The Sword-fishes (*Xiphiidæ*), in which the upper jaw is produced into a long sword-like weapon. The common Mediterranean Sword-fish (*Xiphias gladius*) grows to a length of twelve feet or more. (6) The Goby family (*Gobiidæ*), including the true "Gobies" (*Gobius*), and the Dragonets (*Callionymus*). (7) The *Cottidæ*, comprising the little "Bullhead" (*Cottus gobio*) of streams, and the "Father-lasher" (*C. scorpio*) of our coasts, together with the Gurnards (*Trigla*) and other allied types. (8) The *Blenniidæ*, comprising the Blennies (*Blennius*), the Viviparous Blennies (*Zoarces*), and the Wolf-fishes (*Anarrhicas*). (9) The *Pediculati*, or "Angler" family, of which the common "Fishing-frog" (*Lophius piscatorius*) is a good example.

SUB-ORDER D. PLECTOGNATHI.—This sub-order is characterised by the fact that the maxillary and præmaxillary bones are immovably connected on each side of the jaw. The endoskeleton is only partially ossified, and the vertebral column often remains permanently cartilaginous. The exoskeleton is in the form of ganoid plates, scales, or spines. The ventral fins are generally wanting, and the air-bladder is destitute of a duct.

The most remarkable fishes of this section are the Trunk-fishes (*Ostraciontidæ*), in which the body is entirely enclosed, with the exception of the tail, in an immovable case, composed of large ganoid plates, firmly united to one another at their edges.

Besides the Trunk-fishes, this section also includes the File-fishes (*Balistidæ*) and the Globe-fishes (*Gymnodontidæ*).

Sub-order E. Lophobranchii.—This is a small and unimportant group, mainly characterised by the peculiar structure of the gills, which are arranged in little tufts upon the branchial arches, instead of the comb-like plates of the typical Bony Fishes. The endoskeleton is only partially converted into bone, and the exoskeleton, by way of compensation, consists of ganoid plates. The swim-bladder is destitute of an air-duct.

The singular Sea-horses (*Hippocampidæ*), now kept in most of our large aquaria, belong to this sub-order, but the only point about them which requires notice is the curious fact that the males in this family are provided with a sort of marsupial pouch, into which the eggs are placed by the female, and to which the young, when hatched, can retire if threatened by any danger. This singular cavity is only found in the males, and is situated at the base of the tail. In the allied genus *Solenostoma* the female fish has a brood-pouch formed out of the ventral fins, in which the eggs are carried. More familiar than the Sea-horses are the Pipe-fishes (*Syngnathidæ*), of which one species occurs commonly on our shores.

CHAPTER L.

GANOIDEI.

Order IV. Ganoidei.—The fourth order of fishes is the large and important one of the *Ganoid* fishes, represented, it is true, by few living forms, but having an enormous development in past geological epochs. For this reason the study of the Ganoid fishes is one which claims considerable attention.

By Dr Günther the Ganoids are included with the Elasmobranchs in a primary division of Fishes to which the name of *Palæichthyes* is given, and which is defined by the possession of a rhythmically contractile bulbus arteriosus, the presence of a spiral valve in the intestine, and the fact that the optic nerves either do not decussate, or do so only very partially. The same high authority regards the Dipnoous Fishes as constituting a sub-order of the Ganoids.

The order *Ganoidei* may be defined by the following characters: *The skeleton is cartilaginous or ossified, and there are distinct cranial bones, or the cartilaginous cranium is invested by membrane-bones. The exoskeleton is in the form of ganoid scales or shields, or the skin is naked. Both pairs of limbs are present, and the ventral fins are abdominal in position. The caudal fin is generally heterocercal, but may be diphycercal. A swim-bladder is always present, and has a pneumatic duct. The intestine is*

furnished with a spiral valve. The gills are free, and there is a single gill-slit on each side, protected by a gill-cover. The bulbus arteriosus is furnished with a special muscular coat, is rhythmically contractile, and is provided with several transverse rows of valves.

The condition of the *endoskeleton* varies greatly in different Ganoids. In some forms, such as the Sturgeons and many extinct types, the notochord is persistent, and exhibits no vertebral segmentation beyond the presence of neural and hæmal arches. In such forms, the cartilaginous cranium is more or less largely protected by membrane-bones. In all the living Ganoids except the Sturgeons, the notochord is more or less completely ossified, *Polypterus* and *Amia* having amphicœlous vertebræ, while in the Bony Pike (*Lepidosteus*) the vertebral centra are opisthocœlous, or concave behind and convex in front. This is the highest point of development reached in the vertebral column of any Fish. The tail of the Ganoids is generally heteroceral, the vertebral column being prolonged into the upper lobe, as in *Lepidosteus* (fig. 343, A),

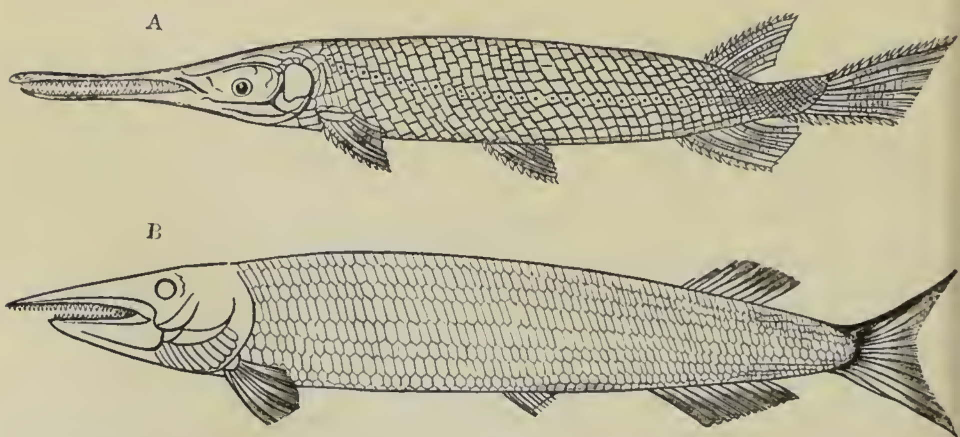

Fig. 343.—A, *Lepidosteus osseus*, the "Gar-Pike" of the American Lakes. B, *Aspidorhynchus*, restored (after Agassiz); a Jurassic Ganoid allied to *Lepidosteus*, but having a diphycercal tail.

or, more markedly, in the Sturgeons. In other cases, as in *Polypterus* (fig. 344, A), the tail-fin is diphycercal, as it is also in many extinct types (fig. 343, B).

Both pairs of *limbs* are present in all recent Ganoids, and the ventral fins are placed far back, in the neighbourhood of the anus. In the living *Polypterus* (fig. 344, A), and in various extinct Ganoids, the fin-rays of the paired fins are arranged so as to form a fringe round a central scaly lobe. Such forms have been termed by Professor Huxley *Crossopterygidæ*, or

"Fringe-finned" Ganoids. In many Ganoids the first rays of certain of the fins, and particularly of the caudal fin, are furnished with one or two rows of little spine-like bones ("fulcra") placed along their upper edges.

The *exoskeleton* may be wanting (as in *Polyodon*), but the body is generally protected by scales of the "ganoid" character, that is to say, scales formed of bone inferiorly and covered by enamel superficially. These scales are often oblong or lozenge-shaped, and do not overlap, but are arranged in oblique rows, each scale articulating with the ones above and below. The recent *Polypterus* and *Lepidosteus* (figs. 343, 344)

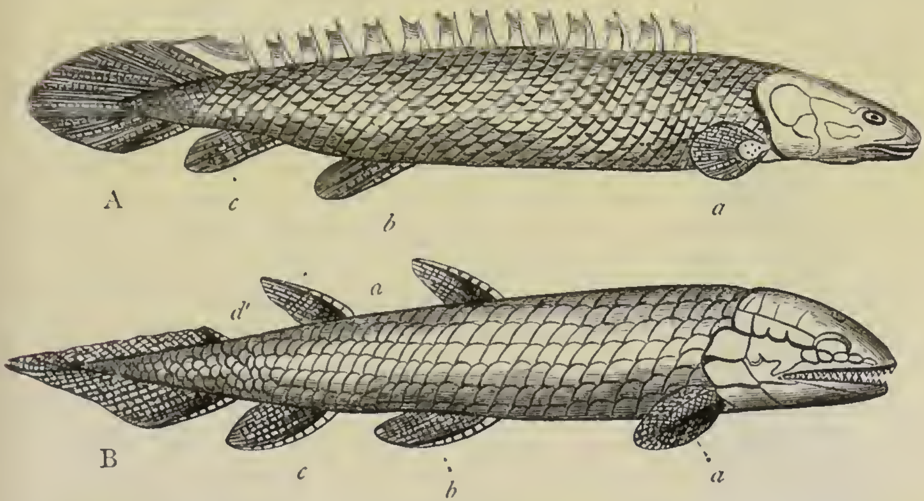

Fig. 344.—Ganoid Fishes. A, *Polypterus*; B, *Osteolepis* (extinct). *a* One of the pectoral fins, showing the fin-rays arranged round a central lobe; *b* One of the ventral fins; *c* Anal fin; *d* Dorsal fin; *d'* Second dorsal fin.

exhibit this type of scales, and it is seen in many fossil forms. In *Amia*, on the other hand, the scales are round and overlap one another. Lastly, in forms like the Sturgeons, scales are wanting, and the body is furnished with detached bony plates or scuta.

With regard to the structure of the *respiratory organs*, the Ganoids agree essentially with the Bony Fishes. They all possess *free* pectinated gills, attached to branchial arches, and enclosed in a branchial chamber, which is protected by an operculum, and is closed by a branchiostegal membrane, usually supported by branchiostegal rays.

There are four complete or biserial gills in the Sturgeons and Bony Pike, but only three complete gills and one uniserial gill in *Polypterus*. In the two former of these there is also an additional half-gill ("opercular" or

"hyoidean" gill) developed on the inner face of the operculum. The Sturgeon (*Acipenser*) and *Polypterus* have "spiracles," or apertures placed on the top of the head and communicating with the pharynx. These spiracles represent an anterior gill-slit, and in the Sturgeons we find within the spiracle the remains of a gill in the form of a "pseudobranchia," or false gill, which only receives arterialised blood, and has no function in the adult. In *Polypterus* both the hyoidean gill and spiracular pseudobranchia are wanting.

The *swim-bladder* is always present, and always communicates with the œsophagus or stomach by a "pneumatic duct," as in the Physostomous Teleosteans. The swim-bladder of *Amia* is cellular and lung-like; and that of *Polypterus* is not only double, but has its duct opening into the ventral side of the gullet, instead of dorsally, as in Fishes generally.

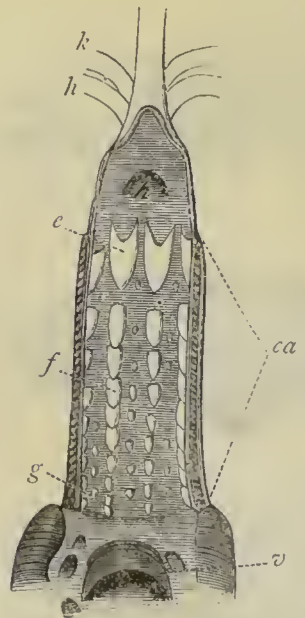

Fig. 345.—Base of the branchial artery of the Bony Pike (*Lepidosteus*) laid open. *ca* Basal portion of the arterial bulb (*conus arteriosus*), with its thickened muscular wall, its transverse rows of valves (*e-g*); *v* Valve between the ventricle and the *conus arteriosus*; *h* and *k* The first two branchial arteries.

In the structure of the *heart* the Ganoids resemble the Elasmobranchs, and differ from the Bony Fishes. The special peculiarity of the so-called "Ganoid type" of heart is that the first portion of the arterial bulb, or base of the branchial artery, is furnished with a special stratum of striated muscular fibres, by which it is enabled to contract rhythmically, and thus to act as a continuation of the heart. Not only is this the case, but it is furnished in its interior with several transversely-arranged rows of valves (fig. 345, *e-g*), in place of the single pair of valves which separates the ventricle from the arterial bulb in the Teleosteans. This muscular, contractile bulb, with its numerous internal valves, is usually spoken of as a *conus arteriosus*, to distinguish it from the simple, thin-walled "bulbus arteriosus" of the Bony Fishes.

As regards their *alimentary canal*, the only special point to notice is the presence in the intestine of the so-called "spiral valve"—*i.e.*, of a spiral reduplication of the mucous membrane which winds round the interior of the tube. In the Bony Pike, however, the spiral valve is rudimentary. It may further be noted that the intestine does not terminate in a "cloaca."

The *reproductive organs* of the Ganoids are peculiar in the

fact that, except in *Lepidosteus*, the generative ducts are not directly continuous with the generative glands, but terminate in funnel-shaped internal openings into which the ova and spermatozoa escape by dehiscence. The generative ducts open, along with the urinary ducts, by a common aperture placed in the middle line behind the anus, a pair of "abdominal pores" intervening between the two.

As regards their *distribution in space*, there are at the present day only seven known existing genera of Ganoids—viz., *Lepidosteus*, *Polypterus*, *Calamoichthys*, *Amia*, *Acipenser*, *Scaphirhynchus*, and *Polyodon* (*Spatularia*)—all of which are found only in the northern hemisphere, and are wholly or partially confined to fresh water.

On the other hand, as regards their *distribution in time*, the Ganoids exhibit a marvellous development in the earlier periods of the earth's history, beginning to decline in numbers when the Secondary period is reached, and becoming gradually fewer and fewer in the Tertiaries. A large number of families of Ganoids are wholly extinct, and have no representatives at all at the present day. One of the most remarkable of these groups of extinct Ganoids is that of the *Ostracostei* or "Placoderms"—a group which is further of interest as comprising the earliest known remains of Fishes which have been as yet brought to light. In this ancient family, the head and anterior part of the body were incased in large bony plates, partially enamelled, and superficially sculptured; and the notochord was persistent. All the Placoderms are either Silurian or Devonian, and well-known genera are *Pteraspis*, *Cephalaspis*, *Coccosteus*, and *Pterichthys*. The remaining families of fossil Ganoids for the most part approach more nearly to living forms, and are generally of the "Lepidoganoid" type, having the body clad with ganoid scales like those of the recent *Lepidosteus* and *Polypterus*. The Palæozoic Ganoids have all "heterocercal" tails; and forms with "diphycercal" tails do not appear till the Secondary period is reached. Fossil Sturgeons (*Acipenser*) occur in the Eocene Tertiary; and the allied group of the Paddle-fishes is represented by the genus *Chondrosteus* in rocks as early as the Lias.

Among the living Ganoids, the Sturgeons (*Acipenseridæ*) are characterised by the possession of rows of large bony shields on the body (fig. 326), the tail being very heterocercal, the mouth toothless, the notochord persistent, and the head covered with dermal bones. The Sturgeons are large fishes which inhabit the rivers or seas of the north temperate zone. As they deposit their spawn in rivers, they may be considered as essentially freshwater fishes. They are of commercial importance, as *isinglass* is obtained from their air-bladder, while the roe is largely used as a delicacy under the

name of *caviare*. Allied to the true Sturgeons is the genus *Scaphirhynchus*, including fresh-water fishes, of which the Shovel-nosed Sturgeon of the Mississippi basin is the best known. Other species occur in Central Asia. Also nearly allied to the Sturgeons are the Paddle-fishes (*Polyodon* or *Spatularia*), in which the skin is naked or furnished with minute bony plates, and the snout is prolonged into a long paddle-shaped flexible process. The Paddle-fishes are of very large size, one species inhabiting the Mississippi, while another is found in the great rivers of China.

The genus *Polypterus*, with a single living species (the *P. bichir* of the rivers of tropical Africa), is the type of another group of Ganoids. The scales in *Polypterus* are rhomboidal, and arranged in transverse rows (fig. 344, A), the dorsal fin is broken up into a number of finlets, each with a spine in front, and the tail is diphycercal. The pectoral fins have a scaly axis, and are thus of the Crossopterygious type. The genus *Calamoichthys*, of Old Calabar, is closely related to *Polypterus*, but ventral fins are wanting.

Another family of recent Ganoids is represented by the so-called "Mud-fish" (*Amia calva*) of the fresh waters of North America, in which the scales are rounded and overlap one another. The swim-bladder of *Amia* is cellular, and can apparently be used as an organ of aerial respiration.

Lastly, another family of existing Ganoids is represented by the so-called "Bony Pikes" or "Gar-pikes" (*Lepidosteidæ*) of the fresh waters of North America and Cuba. The best-known species of the genus *Lepidosteus*, which alone forms this family, is the *Lepidosteus osseus* of the United States. The scales in this genus (fig. 343) are rhomboidal and enamelled, and are arranged in oblique transverse rows. The skeleton is completely ossified, and the vertebræ have opisthocœlous centra, while the tail is heterocercal. The air-bladder is cellular, and, as in the case of *Amia*, seems to be capable of acting as a lung.

CHAPTER LI.

ELASMOBRANCHII AND DIPNOI.

ORDER V. ELASMOBRANCHII (= *Selachii*, Müller; *Placoidei*, Agassiz; *Holocephali* and *Plagiostomi*, Owen).—This order includes the Sharks, Rays, and Chimæræ, and corresponds with the greater and most typical portion of the *Chondropterygidæ* or Cartilaginous fishes of Cuvier. The order is distinguished by the following characters: *The skull and lower jaw are well developed, but there are no cranial bones, and the skull consists of a single cartilaginous box, without any indication of sutures. The vertebral column is sometimes composed of distinct vertebræ, sometimes cartilaginous or sub-notochordal. The exoskeleton is in the form of placoid granules, tubercles, or spines. There are two pairs of fins, representing the limbs, and supported by cartilaginous fin-rays; and the ventral fins are placed far back near the anus.*

The pectoral arch has no clavicle. The heart consists of a single auricle and ventricle, and the bulbus arteriosus is rhythmically contractile, is provided with a special coat of striated muscular fibres, and is furnished with several transverse rows of valves. The gills are pouch-like. The intestine has a spiral valve.

The *exoskeleton* of the Elasmobranchs is of what Agassiz termed the "placoid" type, consisting not of proper scales, but of calcified dermal papillæ, which do not form a continuous covering. In some cases the skin is naked, but the exoskeletal structures usually have the form of detached grains, tubercles, or spines of bony or dentinal matter, commonly having the microscopic characters of teeth. In the so-called "shagreen" of the Dog-fishes and Sharks, the exoskeleton is composed of very small and close-set tooth-like processes (fig. 317, *d*.) In other cases again, as in the Thornback Rays and Spinous Shark, the dermal ossifications have the form of a bony disc, from the upper surface of which springs a sharp recurved spine of dentine (fig. 317, *c*).

The *endoskeleton* of the Elasmobranchs is essentially cartilaginous, and for this reason the name of *Chondropterygii* is often given to the order. The condition of the axial skeleton is very varied, the notochord being in some cases persistent and unconstricted, whereas in other forms complete vertebral segmentation occurs. In this latter case, as in Sharks and Rays, the vertebral centra are more or less hardened by the deposition of lime-salts in the primitive cartilage. The extremity of the vertebral column is usually bent upwards, so that the tail is markedly heterocercal (fig. 347, A); but in a few cases the tail is diphycercal. The skull is always a cartilaginous capsule, without divisions; and the cartilaginous mandible is attached to the side of the skull by a movable suspensorium. There are from five to seven cartilaginous branchial arches, but these are attached superiorly to the front part of the vertebral column.

The pectoral arch is not connected with the skull, and the pectoral fins are well developed. The ventral fins are placed far back, and the pelvic arch carries in the males a pair of special external copulatory organs known as the "claspers."

The *respiratory organs* of the Elasmobranchs differ from those of the Teleosteans and Ganoids in the fact that the branchiæ are contained in a series of pouches (almost always five in number) on each side of the neck, each pouch having a separate internal opening into the pharynx, and a separate external opening or gill-slit (fig. 347, A). The branchiæ are thus not contained in a common branchial chamber on each

side, nor is there a gill-cover closing a single gill-slit. The mode in which the gill-pouches are formed is as follows: Each branchial arch gives rise to a strong membranous partition or septum (fig. 346, *s*) which extends outwards to the skin, and which thus forms the boundary of a gill-pouch. Each branchial arch really gives origin to a double series of branchial laminæ (as in Teleosteans), but these laminæ are now fixed along their inner sides, along the whole or the greater part of their length, to the *opposite* faces of these septa (fig. 346, *br*). It follows from this that in the 2d, 3d, and 4th gill-pouches there are two sets of branchiæ, one on each side of the pouch, but these are the half-gills derived from successive arches. In the 1st gill-pouch there are also branchial lamellæ on both sides, but the anterior of these are derived from a half-gill belonging to the hyoid arch. On the other hand, in the 5th gill-pouch there is only the half-gill derived from the fourth branchial arch, and there are no branchial laminæ on the hinder wall of this pouch. In the singular *Chimæræ* (*Holocephali*), the arrangement above described is so far departed from, that the branchial pouches on each side open by a common external aperture, which is closed anteriorly by an integumentary fold representing a gill-cover.

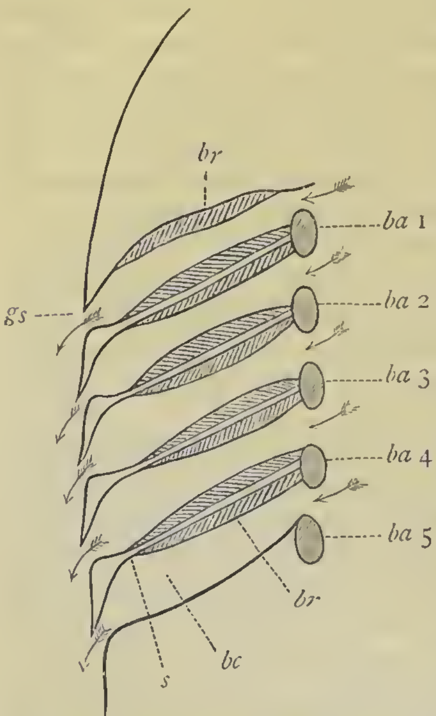

Fig. 346.—Diagrammatic representation of the gill-pouches and arrangement of the gills in an Elasmobranch. *ba* 1—*ba* 5 Branchial arches transversely divided; *bc* One of the branchial pouches; *gs* One of the external gill-slits; *s* One of the septa which separate the different gill-pouches; *br* Branchiæ. The arrows show the direction of the water-currents.

The so-called "*spiracles*" of the Elasmobranchs are the external apertures of the first visceral clefts, and they are placed upon the top of the head, behind the eyes, in all those forms in which they are persistent. They lead into tubes which open into the pharynx, and they contain in the embryonic state a functional gill, which persists in the adult as a functionless "pseudobranchia."

The *heart* of the Elasmobranchs is of the "Ganoid" type, the dilated base of the branchial artery forming a "conus

arteriosus," which is furnished with a special coat of muscular fibres, and is provided internally with from two to five transverse rows of valves. It contracts rhythmically, and acts as a continuation of the ventricle.

As regards the *alimentary canal*, the duodenum is exceedingly short, and is directly succeeded by a short large intestine, the interior of which is furnished with a well-developed "spiral valve" (fig. 331, B). The intestine opens into a dilated chamber or "cloaca," into which the ducts of the generative glands and urinary organs also open.

No *swimming-bladder* is ever developed in any Elasmobranch, though its rudiment may sometimes be detected.

The *brain* is exceptionally well developed, the olfactory lobes giving off long anterior prolongations, the cerebral hemispheres being unusually large, the optic lobes proportionately small, and the cerebellum sufficiently developed to partially roof over the fourth ventricle.

The *kidneys* are comparatively compact, and the terminations of the ureters unite to open, along with the vasa deferentia in the males, into the "cloaca."

The *reproductive organs* of the males consist of two testes, with efferent ducts which open along with the ureters into the cloaca. External accessory organs, previously mentioned as "claspers," are also present. In the females there is often only a single ovary, but in other cases there are two, and in all cases the oviducts are paired. The oviducts have a common internal aperture, and their upper portion is glandular, having in many cases the function of secreting a leathery or horny "purse," in which the ovum is contained. The lower part of the oviduct forms a dilated pouch, or "uterus," within which the embryo is in some cases retained until development has proceeded to a considerable length. In such cases—in which the parent is said to be "viviparous"—the uterine dilatation may merely act as a brood-pouch for the young animal, or the embryo may actually form a connection with its lining membrane by a kind of "placenta." The oviducts open into the cloaca by a separate aperture placed behind the opening of the urinary ducts.

As regards their *distribution in space*, the vast majority of the Elasmobranchs are marine in habit. There are forms, however, both of Sharks and Rays, which are known as inhabiting inland waters.

With regard to their *distribution in time*, the Elasmobranchs are among the most ancient of fishes, being represented by the fin-spines or shagreen of Shark-like fishes (*Onchus* and

Sphagodus) in rocks as old as the Silurian. The Palæozoic Elasmobranchs belong principally to the group of the "Cestracionts," but remains of Rays occur in Carboniferous strata. The true Sharks do not make their appearance till the Mesozoic period is reached. Lastly, the Chimæroids (*Holocephali*) have been alleged to occur in the Devonian, and have a number of undoubted representatives (*Ischiodus*, *Ganodus*, *Elasmodus*, *Edaphodus*, &c.) in the Mesozoic rocks.

The order *Elasmobranchii* is divided into two sub-orders: the *Holocephali*, characterised by the mouth being terminal in position, and there being only a single external gill-slit; and the *Plagiostomi*, in which the mouth is transverse, and placed

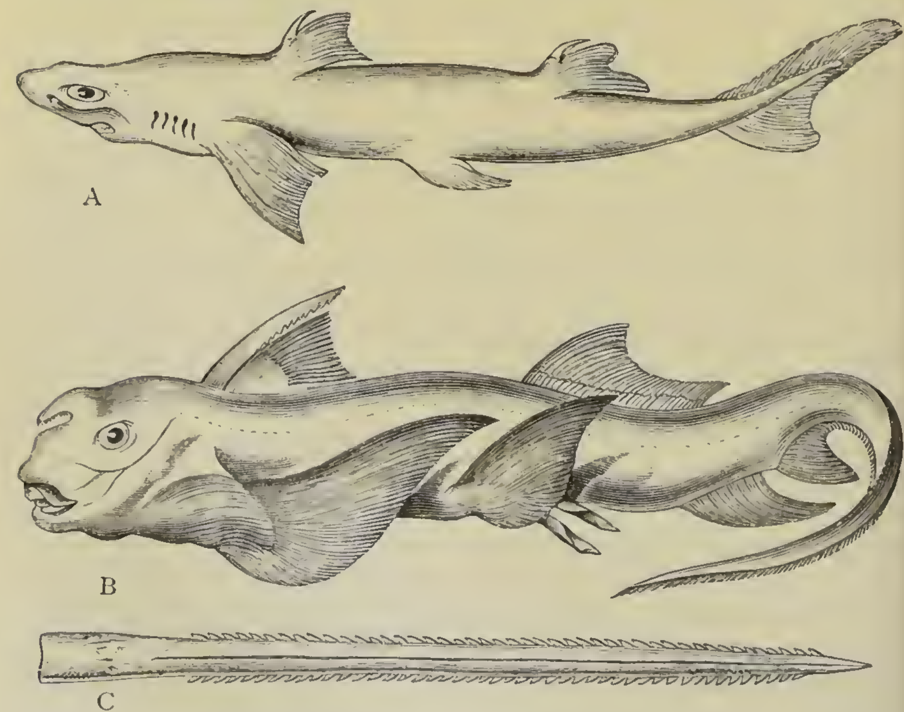

Fig. 347.—A, *Acanthias vulgaris*, one of the Dog-fishes. B, *Chimæra monstrosa*. C, Tail-spine of an Eagle-ray (*Myliobatis*).

on the under surface of the head (fig. 347, A), and there are from five to seven branchial apertures on each side of the neck.

SUB-ORDER A. HOLOCEPHALI.—This sub-order includes certain curious fishes, of which the only living forms are the *Chimæridæ*. The notochord is persistent; but the neural arches are cartilaginous, as is the skull also. The maxillary and palatine cartilages are confluent with the skull, and the "jaw" thus formed carries two pairs of broad crushing dental plates, against which two mandibular teeth bite. The skin is

naked; the first ray in the first dorsal fin is in the form of a great spine or "ichthyodorulite"; and the tail is long and slender, and is diphycercal in shape. There are four branchial pouches, but these are incomplete, and open on the side of the neck by a single external gill-slit (fig. 347, B), which is protected by a rudimentary cartilaginous gill-cover. Spiracles are wanting. The only two living genera of *Holocephali* are *Chimæra* and *Callorhynchus*. Of the former, the best-known species is the *Chimæra monstrosa* (fig. 347, B), sometimes called the "King of the Herrings." It is found in the seas of Europe, Japan, and the Cape of Good Hope. *Callorhynchus* is distinguished by the possession of a cartilaginous prominence on the end of the snout.

SUB-ORDER B. PLAGIOSTOMI.—This sub-order comprises the Sharks, Dog-fishes, and Rays, and is characterised by the fact that the mouth is transverse, and is placed on the under side of the snout (fig. 347, A). The notochord is more or less segmented, and there are generally distinct vertebral centra. The lower jaw possesses a distinct suspensorium, and both jaws are armed with numerous teeth. The gill-pouches are completely separate, and open by separate gill-slits. There are usually five pouches and gill-slits, but in a few Sharks there may be six or seven. The nasal apertures are placed below the snout, and there are two spiracles behind the eyes.

By Professor Owen the Plagiostomes are divided into three sections, termed respectively the *Cestraphori* (Port Jackson Sharks), the *Selachii* (Sharks and Dog-fishes), and the *Batides* (Rays).

A. CESTRAPHORI.—In this division there is a strong spine in front of each dorsal fin, and the back teeth are obtuse (fig. 348). The only living representatives of this group belong to the genus *Cestracion*, of which four species are known, all inhabiting the Pacific. The best-known species is the Port Jackson Shark (*Cestracion Philippi*) of Australian seas. The teeth of all the *Cestraphori* are adapted for crushing Crustaceans and Molluscs, and all the living forms are comparatively small. The pavement-like back teeth and the fin-spines of Sharks of this group are abundant as fossils, the earliest being found in the Silurian rocks.

B. SELACHII.—This group comprises the true Sharks and Dog-fishes, and is characterised by the fact that the body is cylindrical, and not flattened, and the branchial apertures are placed on the side of the neck (fig. 347, A). The skin is covered with minute dermal denticles, constituting "shagreen." The teeth are usually sharp-edged, and adapt the fish for killing and devouring large animals. Some, however, have small teeth, and feed principally upon Invertebrates. The teeth are arranged in several rows, and during life the cartilaginous jaws are so far flexible that their margins can be partially everted, thus bringing more than one row of teeth into use at a time; but the innermost rows are principally employed to replace the outer ones as worn out.

The principal families of the *Selachii* are the following :—

(1.) *Carchariidæ*, comprising the true Sharks of tropical seas, of which the "Blue Shark" (*Carcharias glaucus*) is a good example. Other forms are the Hammer-headed Shark (*Zygæna*), and the small Sharks known as "Hounds" (*Mustelus*).

(2.) *Lamnidæ*, comprising the "Porbeagles" (*Lamna*), the Basking

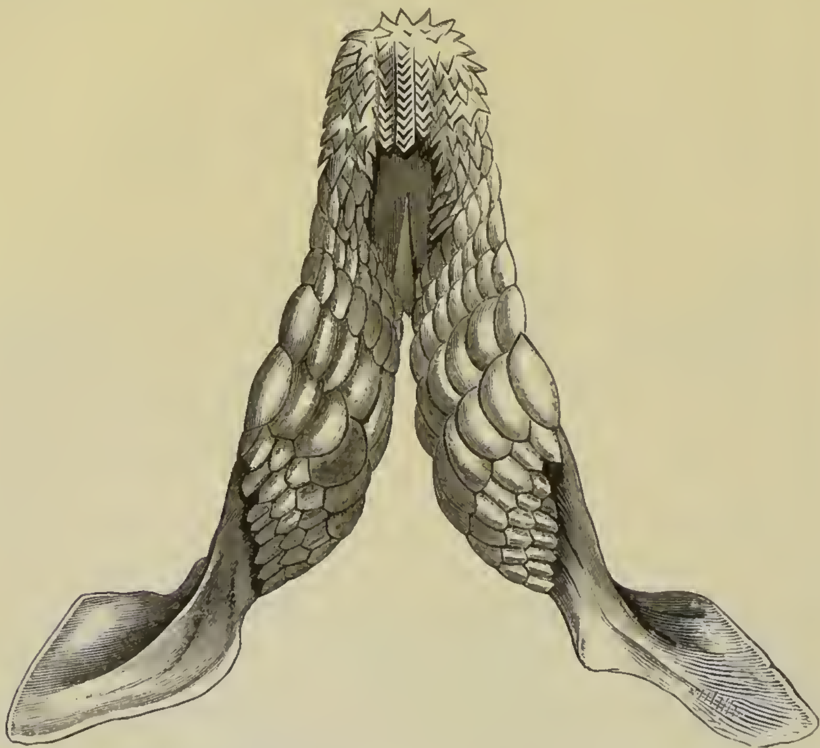

Fig. 348.—Upper jaw of Port Jackson Shark (*Cestracion*), showing the pavement of crushing teeth. One-half the natural size. (After Owen.)

Sharks (*Selache*), and the great *Carcharodon* of the tropics, which grows to forty feet in length. Fossil teeth of *Carcharodon* prove the existence in late Tertiary times of still more gigantic members of this genus.

(3.) *Rhinodontidæ*, represented only by the huge *Rhinodon typicus* of the Indian Ocean, which grows to over fifty feet in length, but has very small teeth and is quite harmless.

(4.) *Scyllidæ*, or ordinary Dog-fishes, represented in British seas by the common Spotted Dog-fishes (*Scyllium canicula*, and *S. catulus*).

(5.) *Spinacidæ*, or Spiny Dog-fishes, represented by the common "Picked Dog" (*Acanthias vulgaris*, fig. 347, A) of British seas, and the Greenland Shark (*Læmargus borealis*) of northern seas.

(6.) *Rhinidæ*, comprising only the somewhat Ray-like Monk-fish (*Rhina squatina*) of temperate and tropical seas.

C. Batides.—This group includes the Rays and Skates, distinguished by the fact that the body is flattened out so as to form a sort of rhomboidal disc, the greater part of which is made up of the largely-developed pectoral fins (fig. 349). The branchial openings are placed on the ventral surface of the body, behind the mouth. There is no anal fin, as there is

in the *Selachii*. The tail is long and slender, and often armed with spines. The following are the chief families of *Batides*:—

(1.) *Pristidæ*, including only the "Saw-fishes" (*Pristis*), in which the snout is elongated so as to form a long, flexible, sword-like organ, the sides of which are furnished with strong tooth-like spines, and which is used as an offensive and defensive weapon.

(2.) *Rhinobatidæ*, comprising the "Beaked Rays." The typical genus *Rhinobatis* is wholly tropical and subtropical in its range.

(3.) *Torpedidæ*, comprising the "Electric Rays." Three species occur in the Mediterranean, and one of them is occasionally found in British seas.

(4.) *Raiidæ*, including the ordinary Skates and Rays. Common British species are the Skate (*Raia batis*) and the Thornback (*R. clavata*). In many of the *Raiidæ*, the males have most of the teeth pointed, while those of the females are blunt and flat.

(5.) *Trygonidæ*, comprising the "Sting-Rays" (*Trygon*), in which the tail carries upon its upper surface, in place of a dorsal fin, a strong serrated spine, which can be used as an organ of defence.

Fig. 349.—Batides. *Raia marginata*, one of the Skates. (Reduced one-sixth.) (After Gosse.)

(6.) *Myliobatidæ*, comprising the "Eagle-Rays" (*Myliobatis*), the "Horned Rays" (*Cephaloptera*), and other allied forms. The teeth in this family have the form of blunt dental plates, which cover both the upper and lower jaws as a kind of mosaic pavement, and are used for crushing shell-fish and other marine animals. The Rays of this family often grow to an enormous size, and are found in tropical and temperate seas.

ORDER VI. DIPNOI.—This remarkable order comprises three living genera only (*Lepidosiren*, *Protopterus*, and *Ceratodus*), and is defined by the following characters: *The body is fish-like in shape, and is covered with horny overlapping scales of the cycloid type. The notochord is persistent, and devoid of vertebral segmentation, and the skull is invested by membrane bones. Both the pectoral and ventral fins are present, and the latter are placed far back. The tail is diphycercal or heterocercal, the latter in extinct forms only. The respiratory organs have the form of free branchiæ carried upon branchial arches, and enclosed in a common branchial chamber on each side, which opens by a single vertical gill-slit protected by an operculum. The swim-bladder is sacculated, sometimes double, and it opens into the gullet by a duct. It can be used as a lung. The heart is of the "Ganoid" type,*

the base of the branchial artery having a special muscular coat, and being furnished with numerous valves internally. The intestine has a spiral valve, and terminates in a "cloaca." The nasal sacs open posteriorly into the mouth.

The *Dipnoi* are of special interest as being in many respects intermediate in their characters between the Fishes and the Amphibians. At the same time, there can be no question as to their being properly referable to the class *Pisces*, and as being closely allied to the Ganoids, with which order they are, indeed, united by Dr Günther. They are also of interest as throwing light upon the structure and affinities of many extinct types of Fishes.

The body in the *Dipnoi* is quite fish-like, and is covered with cycloid scales, which are of remarkably large size in *Ceratodus*. The hinder end of the body is fringed by a long caudal

Fig. 350.—A, *Lepidosiren paradoxa*, one of the Mud-fishes. B, Front of the mouth of the same, showing the teeth. C, One of the overlapping scales, enlarged.

fin, which is diphycercal in all the living forms, but is conspicuously heterocercal in certain of the extinct types. The pectoral and ventral fins are both present, but vary much in form. In *Lepidosiren* (fig. 350) they are in the form of awl-shaped fila-

ments, and in the allied *Protopterus* they have much the same shape, but are bordered by a narrow fringe supported by rays. On the other hand, in *Ceratodus*, and in various extinct genera, the fins agree with those of the Crossopterygian Ganoids, having an axial scaly lobe fringed by the fin-rays on both sides. In *Ceratodus* the pectoral fin (fig. 351) is supported by a carpal cartilage giving origin to a median cartilaginous axis, formed by a succession of joints, which, in turn, support on each side a lateral series of jointed branches, these, finally, bearing the fin-rays.

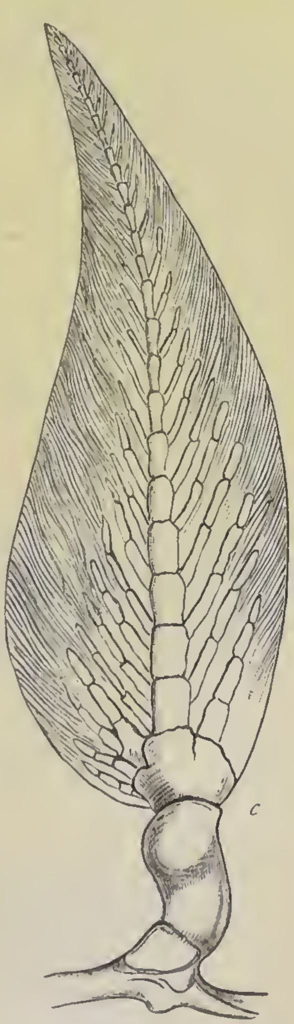

Fig. 351.—Skeleton of the pectoral fin of *Ceratodus*, showing the median axis and divergent branches on each side. *c* Carpal cartilage. (After Günther.)

The *branchiæ* of the *Dipnoi* are arranged essentially upon the type of those of the Teleosteans and Ganoids. The branchial filaments are carried upon branchial arches, which are five or six in number, but all of which do not carry gills. There is a common gill-chamber on each side, which is closed by a gill-cover, protecting a single vertical gill-slit. *Protopterus* shows the remarkable Amphibian character that there are placed above the gill-slit three *external* branchial tufts, which persist throughout life, or at any rate to a late period.

The *air-bladder* of the *Dipnoi* is sacculated, and opens into the gullet by a pneumatic duct. In *Ceratodus* it is single, but its internal compartments have a laterally symmetrical arrangement. In this genus the air-bladder has no true pulmonary artery, but it receives blood from a branch of the subvertebral aorta (the cœliac artery), and its veins form a pulmonary vein which opens into the auricle of the heart. In *Lepidosiren* and *Protopterus* the air-bladder is divided into two halves, and is cellular internally. In these genera, the air-bladder is supplied with venous blood by a true pulmonary artery derived from a hinder branchial artery; and the arterialised blood is returned to the heart by pulmonary veins, which open into the

ventricle directly (*Protopterus*), or through the intervention of a left auricle (*Lepidosiren*).

The *heart* of the *Dipnoi* is of the "Ganoid" type, the base of the branchial artery forming a rhythmically contractile "conus arteriosus," in the interior of which are numerous valves. In *Ceratodus* these valves have a transverse direction, but in *Lepidosiren* and *Protopterus* they are longitudinally disposed. The heart shows an imperfect division into a right and left half, which in *Ceratodus* is "limited to the ventricle" (Günther). In *Lepidosiren* and *Protopterus*, on the other hand, there is an incomplete division of the auricle into a right and left half.

The *intestine* in the *Dipnoi* possesses a spiral valve, as in Ganoids and Elasmobranchs; and the rectum opens into a "cloaca," into which the generative and urinary ducts also discharge themselves by a common urogenital aperture.

Lastly, the *nasal sacs* in the *Dipnoi* are peculiar in the fact that they open posteriorly into the mouth, as in no other fishes except the *Myxinoids*. The anterior nostrils are placed either entirely within the upper lip, and thus inside the mouth, or close to the margin of the upper lip.

As regards their *distribution in space*, the three living genera are exclusively confined to the inland waters of hot regions. *Lepidosiren* (with one species) is South American; *Protopterus* (with one species) is African; and *Ceratodus* (with two species) is Australian.

With regard to their *distribution in time*, the living genus *Ceratodus* is represented in rocks as ancient as the Trias by undulated dental plates (fig. 352) closely similar to the "molars"

Fig. 352.—A, Dental plate of *Ceratodus serratus*, Keuper. B, Dental plate of *Ceratodus altus*, Keuper. (After Agassiz.)

of the Australian Mud-fish. The order is, however, represented in the Palæozoic period by forms of much greater antiquity. The most important of these are the Devonian and Carboniferous group of the *Ctenodipterini*, comprising the genera *Dipterus* and *Ctenodus*. These ancient types of the

Dipnoi differ from all existing forms in their strongly heterocercal tails, as well as in other characters.

The three living genera of *Dipnoi* form a special division of the order (*Sirenoidei*), characterised by their horny cycloidal scales and diphycercal tails. The genus *Lepidosiren* is represented by a single species (*L. paradoxa*, fig. 350), which inhabits fresh waters in the basin of the river Amazon. It grows to a length of three or four feet, with an eel-shaped body, filamentous limbs, and rudimentary eyes. The upper and lower jaws support each a pair of cuspidate dental plates, and two conical vomerine teeth. It is one of the rarest of animals, only four specimens having been hitherto obtained.

The genus *Protopterus* is represented also by one species only (*P. annectens*), which is nearly related in many respects to *Lepidosiren*, but differs in having a fringe to the pectoral and ventral limbs, in the possession of external gill-tufts, and in other less important points. *Protopterus annectens* inhabits tropical Africa, in the rivers of which it seems to be tolerably plentiful in some regions. When the pools which it inhabits dry up, it buries itself in the mud, forming a kind of chamber, in which it remains dormant till the return of the rainy season. In this condition the fish can be exported alive to Europe. It is carnivorous in its habits, and grows to a length of six feet.

Lastly, the genus *Ceratodus* is confined to the rivers and marshes of Queensland (Australia), in which are found the only two known species—viz., *C. Forsteri* (fig. 353), and *C. miolepis*. The former and best-known

Fig. 353.—*Ceratodus Forsteri*, the Australian Mud-fish, reduced in size.

species is known to the natives as the "Barramunda" or "Jeevine," and grows to a length of six feet, and has its body covered with very large cycloid scales. Its paired fins differ widely from those of *Lepidosiren* and *Protopterus*, having the form of pointed scaly lobes, round which the fin-rays are symmetrically disposed. The upper and lower jaws carry each a pair of singular dental plates or "molars," having the form of flattened undulated plates of bone, with lateral prong-like extensions. These dental plates are employed in triturating the leaves upon which the Barramunda feeds, it being an exclusively vegetable-feeding animal. It seems usually to live upon the leaves which have fallen into the water from the neighbouring trees; but it is stated to come out of the water at night, and to betake itself to the mud-flats in the vicinity for the purpose of obtaining food. Whether this be the case or not, there is no reason to doubt but that the swim-bladder can act as an organ of respiration, and that the animal has thus the power of breathing air, when the water which it inhabits becomes impure, or when aerial respiration may be otherwise rendered necessary.

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DIVISION I.—ICHTHYOPSIDA.

CHAPTER LII.

CLASS II.—AMPHIBIA.

THE class *Amphibia* comprises the Frogs and Toads, the Salamandroids, the *Cæciliæ*, and the extinct Labyrinthodonts, and may be briefly defined as follows: As is the case with the Fishes, the embryo is not furnished with an amnion, and the urinary bladder is the only representative of the allantois. As in Fishes, also, *branchiæ or filaments adapted for breathing air dissolved in water are always developed upon the visceral arches for a longer or shorter time.* On the other hand, the Amphibians differ from the Fishes in the fact that *true lungs are always present in the adult; the limbs are never converted into fins; and when median fins are present, as is sometimes the case, these are never furnished with fin-rays.* The limbs, when present, exhibit in their skeleton the same parts as do the limbs of the higher Vertebrates. *The skull always articulates with the vertebral column by means of two occipital condyles. The heart consists of two auricles and a single ventricle. The nasal sacs communicate posteriorly with the pharynx; and the rectum, ureters, and ducts of the reproductive organs open into a common chamber or "cloaca."*

The *integument* of the Amphibians is mostly soft, moist, and glandular, largely concerned in respiration, and generally destitute of exoskeletal structures. Scales are, however, developed in the skin of the Cæcilians, while the extinct Labyrinthodonts possessed a ventral armour of bony scutes. There are also dermal ossifications in the dorsal integument of some of the Tailless Amphibians (*e.g.*, in *Ceratophrys*). Usually mobile pigment-cells are largely developed in the skin, giving to the animal varied colours in different cases, and conferring upon it the power of changing its tint to suit its surroundings.

The condition of the *endoskeleton* varies considerably, but in general the skeleton of the adult is well ossified. The notochord may be partially persistent (as in the Cæcilians),

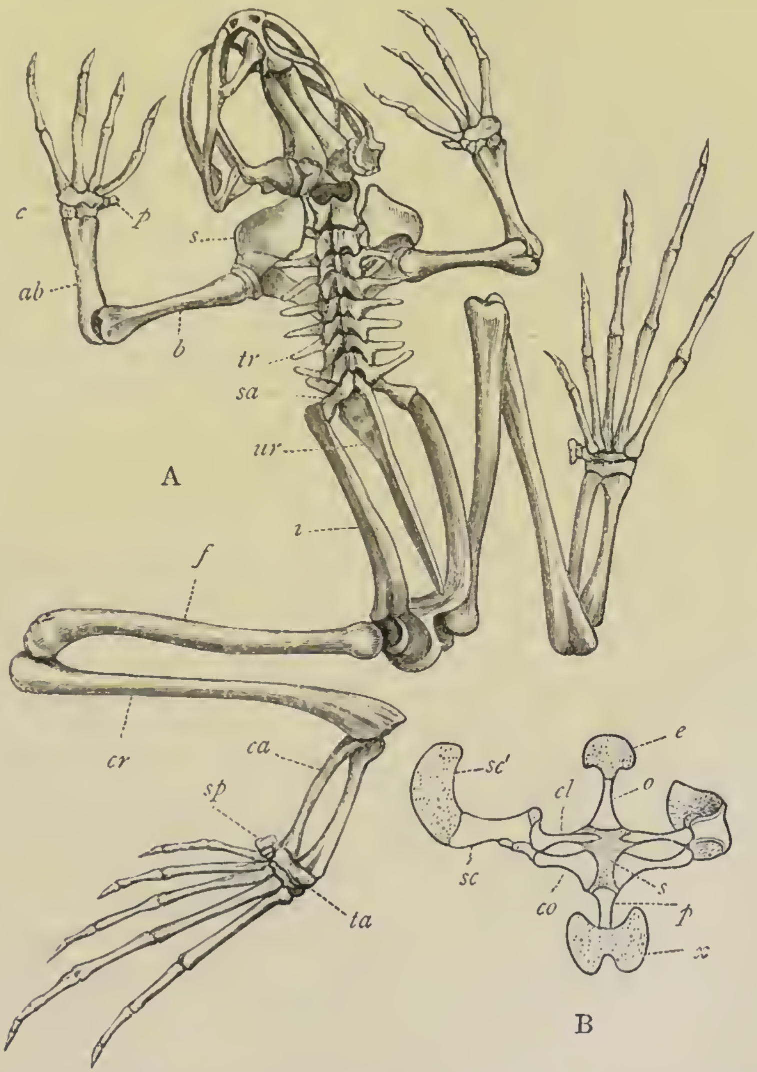

Fig. 354.—A, Skeleton of the Frog (*Rana temporaria*): *tr* Transverse processes of vertebræ; *sa* Sacrum; *ur* Coccyx ("urostyle"); *i* Ilium; *s* Supra-scapula; *b* Humerus; *ab* Conjoined radius and ulna; *c* Carpus; *p* Rudimentary thumb; *f* Femur; *cr* Conjoined tibia and fibula; *ca* Calcaneo-astragalus; *ta* Tarsus; *sp* Spur or "calcar." B, Pectoral arch and sternum of Frog (after Gegenbaur). The dotted parts represent cartilages. *e* Episternum; *o* Omosternum; *p* Body of the sternum; *x* Xiphisternum; *sc'* Supra-scapula; *sc* Scapula; *cl* Clavicle; *co* Coracoid, fused with its fellow on the opposite side (*s*).

but vertebral segmentation is always present. In the Cæcilians, the Perennibranchiate Urodelans, and many of the extinct Labyrinthodonts, the vertebral centra are amphicœlous, as in

Fishes generally. In the Caducibranchiate Urodelans (Salamanders) the vertebral bodies are opisthocœlous, and in the Tailless Amphibians the centra are procœlous. All the Tailed forms have a long vertebral column, but the *Anoura* (Frogs and Toads) never possess more than nine præcoccygeal vertebræ (fig. 354). The sacrum never consists of more than one vertebra. The transverse processes of the vertebræ are very long, and in most cases ribs are wanting, or are represented by cartilaginous rudiments only. Even in those which have ribs (*e.g.*, Cæcilians), the ribs are not connected anteriorly with a sternum. A sternum is, however, present in most Amphibians, and consists in the Frog of a cartilaginous "episternum" (fig. 354, B, *e*), succeeded posteriorly by a long "omosternum" (*o*), which is followed by the body of the sternum, carrying posteriorly a broad gristly "xiphisternum" (*x*).

The *skull* in the Amphibians is largely cartilaginous, but the primitive cartilage undergoes partial ossification, and is also extensively invested by membrane bones. The body of the occipital bone ("basioccipital") is never ossified, but the two exoccipitals are converted into bone, and carry the two occipital condyles which are characteristic of all the Amphibians. The suspensorium of the lower jaw ("quadrate cartilage") remains unossified, and is connected in front with the "quadrato-jugal" bone. The second visceral arch persists as the hyoid, and the third and fourth arches may have rudimentary representatives in the adult.

The pectoral arch consists of a cartilaginous supra-scapula (fig. 354, B, *sc′*), a bony scapula, a coracoid bone, and a clavicle on each side. The pectoral limb is present in all except the Cæcilians, and consists of its usual bones. The manus has five digits in the Tailless Amphibians, but never more than four in the Tailed forms. The pelvic arch is present in all Amphibians except the Cæcilians and *Siren*, and the ilia (fig. 354, A, *i*) are very long and narrow, articulating by their anterior ends with the transverse processes of the single sacral vertebra. The pelvic limb possesses the normal parts.

As regards the *digestive system*, the mouth may be edentulous, but is usually furnished with teeth developed upon the vomers, maxillæ, and palatine bones, and generally on the mandible also. A tongue may be absent or present, and protrusible or the reverse. In the *Anoura* (Frogs and Toads) it is attached in front to the symphysis of the lower jaw, and is divided behind into two pointed lobes, which are directed towards the throat. The alimentary canal usually shows a simple tubular stomach, a coiled small intestine and a short large

intestine, a liver and pancreas being always present. The rectum opens into a cloacal dilatation, which receives also the ducts of the urinary and generative organs.

As regards the *circulatory organs*, the heart and course of the circulation are in young Amphibians essentially similar to what they are in Fishes. At this stage the heart is purely respiratory, and is concerned wholly with driving the venous blood to the gills. The heart of the larval Amphibian (such as the Frog) consists of a single auricle and ventricle, and the base of the aorta is dilated to form a "bulbus arteriosus," from which proceed on each side three branchial arteries which carry the venous blood to the gills. The oxygenated blood is returned from the gills by three branchial veins on each side, the first pair of these going directly to the head, while the last two pairs unite to form the descending aorta. The pulmonary artery is at this stage very minute, and springs from the third or hindermost pair of branchial arteries.

In the adult Amphibians the heart is three-chambered, and consists of two auricles and a common ventricle; but additional cavities are formed, as in Fishes, by dilatations of the great systemic veins where they enter the heart (sinus venosus), and of the base of the aortic arches (bulbus arteriosus).

Viewed as a whole, the heart of an adult Amphibian, as for example the Frog, exhibits the following parts (fig. 355):—

(1.) The "sinus venosus," a blood-sinus formed by the confluence of the great systemic veins where they approach the heart. It lies on the dorsal side of the heart, and opens into the right auricle.

(2.) The "atrium," or apparently single cavity formed by the apposition of the auricles. In reality, this is divided by a delicate partition into a right auricle and a left auricle (fig. 355, *ra* and *la*).

(3.) A single undivided ventricle (*v*) into which both auricles discharge their contents.

(4.) The "bulbus arteriosus" or "truncus arteriosus" (fig. 355, *ta*), representing the dilated base of the aortic arches. The truncus arteriosus divides into two primary divisions (*d*), each of which is externally single, but is divided internally into three compartments, corresponding with the three aortic arches on each side. The first or most anterior aortic arch has placed upon it a singular spongy enlargement known as the "carotid gland" (*cg*), and divides into the carotid and lingual arteries (*ca* and *l*). The second or middle aortic arch (2) unites with its fellow behind the heart, thus forming the systemic or descending aorta (*da*), which runs beneath the vertebral column. The third or most posterior aortic arch (3) divides into the proper pulmonary artery (*pu*), and a great branch which carries venous blood to the skin and is known as the cutaneous artery (*pc*).

The general course of the circulation is as follows: The blood which has circulated through the body enters the general venous circulation, in which is intercalated a renal-portal and an hepatic-portal circulation. The great systemic veins (the right and left superior venæ cavæ and the single inferior vena cava) pour their blood into the "sinus venosus," from which it enters the right auricle. On the other hand, the pulmonary veins, car-

rying the arterialised blood from the lungs, open into the left auricle. As the ventricle is not divided internally into a right and left half, it follows that the contraction of the auricles drives a current of venous blood and one of arterial blood into the common ventricle, so that, theoretically, the ventricle ought to propel *mixed* blood both to the body generally and to the breathing organs. In actual fact, however, the venous and arterial

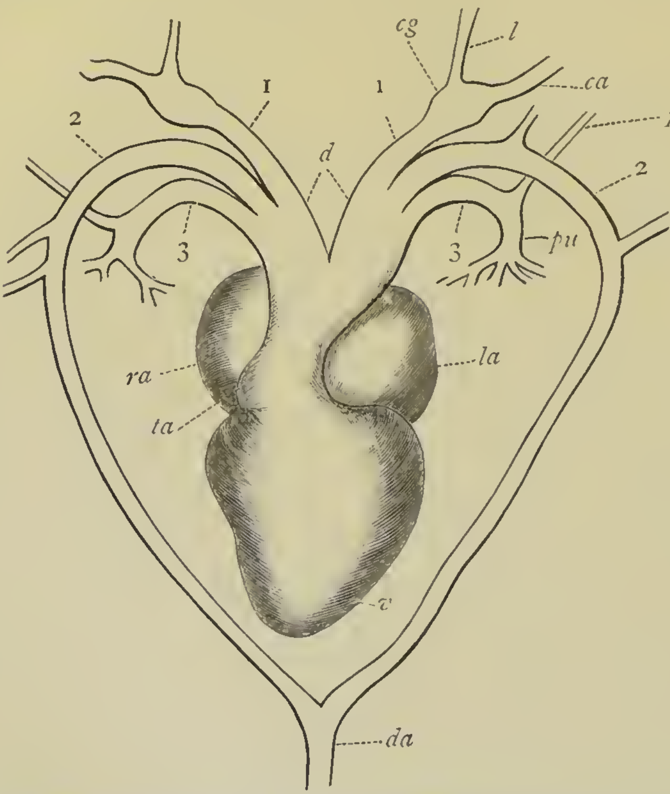

Fig. 355.—Sketch of the heart of a Frog viewed from the ventral side. *v* Ventricle; *la* Left auricle; *ra* Right auricle; *ta* Arterial bulb (truncus arteriosus); *d* Primary divisions of the truncus arteriosus, each consisting of three aortic arches (1, 2, 3). 1, First aortic arch giving origin to the carotid artery (*ca*), and the lingual artery (*l*); *cg* Carotid gland; 2, Second aortic arch, uniting with its fellow on the opposite side to form the systemic aorta (*da*); 3, Third aortic arch, dividing into the pulmonary artery (*pu*), and the cutaneous artery (*pc*).

streams, entering the ventricle from the right and left auricles respectively, are kept to a large extent separate from one another, and are separately distributed through the different aortic arches. It is unnecessary here to describe the mechanism by which this is brought about. The general result is that unmixed venous blood is distributed by the third aortic arches to the pulmonary and cutaneous arteries, by which it is conveyed to the lungs and skin respectively to be aerated. The first aortic arches receive nearly quite pure arterial blood, which is distributed through the lingual and carotid trunks to the head and fore part of the body. Lastly, the second or proper aortic arches receive arterial partially mixed with venous blood, which is distributed by the systemic aorta to the body generally.

The lymphatic system in the Amphibians is peculiar in the

fact that there are no proper lymphatic vessels, but the lymph circulates in lacunar spaces beneath the skin and in great sinuses formed by the mesentery. In the higher Amphibians there are connected with the lymphatic system one or two pairs of pulsating cavities known as "lymph hearts." In the Frog there are two pairs of these, the anterior situated close to the transverse processes of the 3d vertebra, while the posterior lie one on each side of the coccyx.

As regards their *respiratory organs*, all the Amphibians possess branchiæ in the early stages of their life, and all possess lungs in the adult condition. The branchiæ are developed in connection with three branchial arches, separated by clefts which lead into the pharynx. In the earliest stages of development branchial filaments are produced from the outer ends of the branchial arches as three *external* gill-tufts on each side. In those Amphibians which keep their gills throughout life ("perennibranchiate" forms), it is these external branchiæ which are retained. In the higher Amphibians *two* sets of gills are developed, the external branchiæ early disappearing, and being replaced by a set of internal gills developed on the opposed faces of the branchial arches. In all cases, however, these internal gills disappear when the lungs take up their function as air-breathing organs. In the so-called "caducibranchiate" Amphibians, not only do the branchiæ entirely disappear, but the gill-clefts are also obliterated, and the adult animal shows no signs of having ever been branchiate. There are forms, however, such as *Amphiuma* and *Menopoma*, which are so far intermediate between the perennibranchiate and caducibranchiate types that while they lose their gills, they nevertheless retain a branchial aperture on the side of the neck. In all Amphibians the lungs are comparatively simple membranous sacs, without internal divisions or with only rudimentary septa, and they play a comparatively unimportant part in respiration. When the gills are retained throughout life, it is probable that these are the principal breathing organs; and where the gills are lost, the soft and moist skin plays an important part in the process of respiration.

The *kidneys* of the Amphibians discharge their secretion by two ureters, which open separately into the "cloaca." A large urinary bladder ("allantoic bladder"), usually bifid superiorly, is present, and opens into the ventral side of the cloaca, but the ureters do not open into this, and it does not therefore contain the urine. Attached to the upper ends of the kidneys in the Frog are tufts of slender yellow processes, composed of fatty tissue, and known as the "fat bodies"

("corpora adiposa"). These are usually shrunken in winter, and increase in size in summer, but their precise function is not clear.

The *brain* of the Amphibians (fig. 356) is in the main very similar to that of Fishes. The cerebral hemispheres are relatively larger than in Fishes, but they leave the mid-brain uncovered, while the optic lobes are still of large size. The cerebellum is small, and the medulla oblongata and wide fourth ventricle are not covered by it. Eyes are rudimentary and hidden under the skin in a few forms, but are usually present, and may or may not be provided with eyelids. External ears are wanting, but a tympanic cavity and tympanic membrane may be present (in the *Anoura*). In the Frogs the tympanum is visible externally as a circular area of skin, differing from the surrounding integument, placed a little behind the eye on each side.

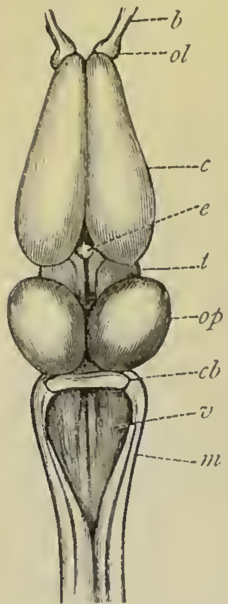

Fig. 356.—Brain of the Frog (*Rana temporaria*), viewed from above. *ol* Olfactory lobes prolonged into the olfactory nerves (*b*); *c* Cerebral hemispheres; *e* Pineal gland; *t* Optic thalami; *op* Optic lobes; *cb* Cerebellum; *v* Fourth ventricle; *m* Medulla oblongata.

The *generative organs* of the male Amphibians consist of a pair of testes placed in close relation to the kidneys, and discharging their contents by efferent ducts which enter the kidney and join the urinary ducts. The ureters thus act as vasa deferentia, and the semen is discharged into the cloaca. In the female Amphibians the oviducts are not directly continuous with the paired ovaries, but each begins by a wide funnel-shaped opening placed far forward in the abdominal cavity. The oviducts are long and coiled, but their lower portions are usually dilated to form a "uterus," and they finally open into the cloaca along with the urinary ducts. Impregnation, except in some Salamanders, is effected outside the body, after extrusion of the eggs, over which the male sheds the semen. In the Land Salamanders the eggs are fertilised prior to extrusion from the body, the impregnated ova being retained within the uterine dilatations of the oviducts. In these "ovo-viviparous" forms the metamorphosis of the young animal is more or less completely undergone within the body of the parent. There are other cases in which the development of the young animal takes place within special integumentary cavities (as in *Pipa*), or in brood-pouches (as in *Nototrema* and *Notodelphys*).

In the majority of the Amphibians, however, the development of the impregnated ova takes place altogether outside the body of the mother, and is attended with a more or less marked *metamorphosis*. This metamorphosis is principally connected with the fact that the Amphibians commence life as water-breathing larvæ, or "tadpoles," provided with branchiæ, whereas in the adult condition they possess lungs; and the extent of the metamorphosis largely depends upon whether or not the larval branchiæ are got rid of in the adult. The larvæ are also at first limbless and furnished with a swimming-tail, whereas the adult has usually limbs, and may be without the tail. Lastly, the larvæ are vegetable-feeders, whereas the adults are carnivorous.

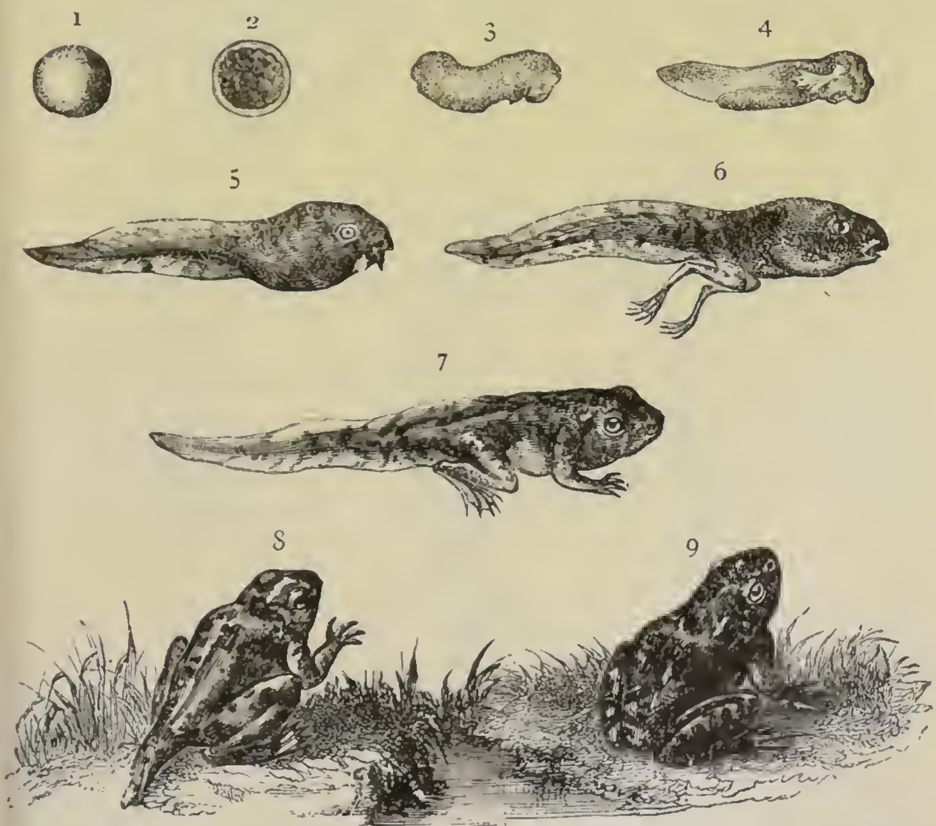

Fig. 357.—Stages in the development of the Frog. 1. The egg; 2. The same after segmentation has taken place; 3. The first stage of the Tadpole; 4. Tadpole in which external branchiæ have appeared; 5. Tadpole in which the external gills have disappeared, and internal branchiæ are developed; 6. Tadpole with the hind limbs; 7. Tadpole in which both pairs of limbs are present; 8. Young Frog with the tail not entirely absorbed; 9. Perfect Frog.

The development of the common Frog (*Rana temporaria*) may be taken as affording an excellent example of the metamorphosis of the higher Amphibians generally (fig. 357). The eggs of the Frog are deposited in water,

and the thin layer of albumen with which each egg becomes invested in its passage through the oviduct swells up on contact with the water, so that the ova cohere and form a gelatinous mass. When first hatched, the young frog is without limbs or gills, and it rapidly develops into what is known as a "tadpole." In this stage (fig. 357, 4) the larva is a minute, limbless, fish-like creature, with a long swimming-tail, and furnished with two sucking discs, or "holders," on the under side of the head behind the mouth, by means of which it can temporarily attach itself to foreign objects. The larva now develops *external* gills, in the form of three pairs of branched filaments placed on the sides of the neck (fig. 358, A and B).

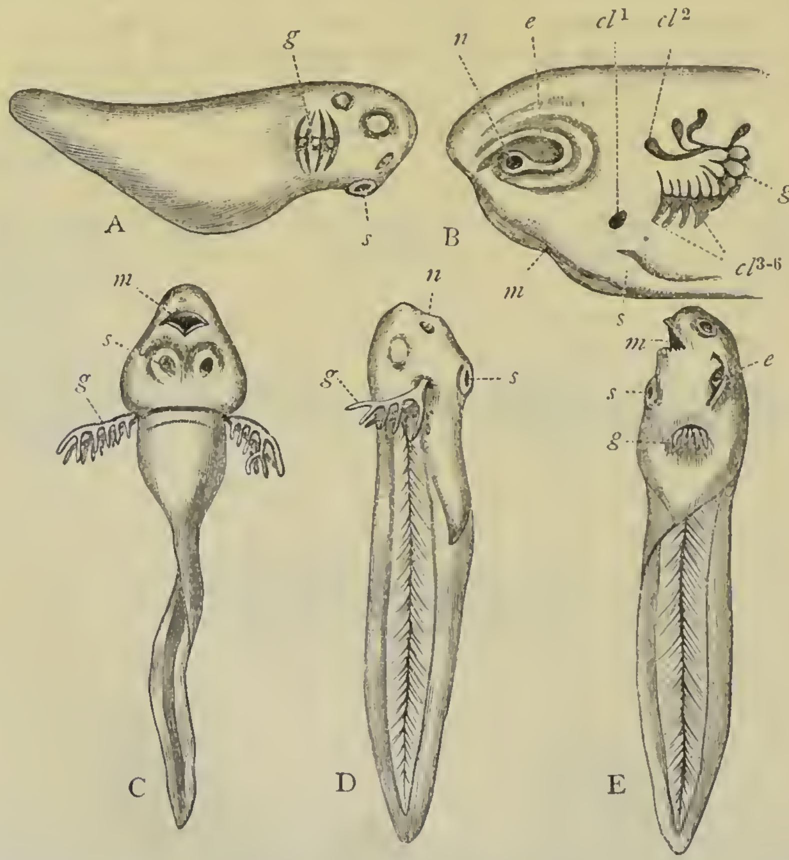

Fig. 358.—Development of the Frog. A, Embryo before hatching, showing the rudimentary gills (*g*) as tubercles upon the visceral arches. B, Side-view of head of Tadpole, a few days after hatching. C, Under side of a Tadpole, some time after hatching. D, Side-view of the same. E, Side-view of an older Tadpole, in which the external branchiæ have nearly disappeared, and the tips of the gills (*g*) protrude from a respiratory pore seen on the left side of the neck by the uncompleted growth of the operculum. *g* Gill-plumes; *m* Mouth; *n* Nasal pit; *e* Eye; *s* Holder; *cl* 1-6, Visceral clefts. (B is after Parker, the rest after Ecker.)

Between the branchial plumes are gill-clefts leading into the throat, and the Tadpole now breathes after the manner of a fish, by taking in water at the mouth and passing it out by the gill-clefts. Each of the three branchial plumes is supplied with venous blood by a branchial artery, derived from one of the three aortic arches on each side, and the arterialised blood is

conveyed away by a branchial vein. The first branchial veins go directly to the head, but the last two pairs unite to form the systemic aorta.

The mouth of the Tadpole (fig. 358, *m*) is placed upon the under side of the head, and is furnished with horny plates on the jaws, forming a kind of beak. The larva lives upon vegetable food, and the intestine is long and spirally coiled. Limbs are still absent.

In the next stage of development, a fold of the skin grows back from the jaw, and forms a kind of opercular fold which gradually covers up the gills. This fold differs from the gill-cover of Fishes in having no representatives of branchiostegal rays or opercular bones (unless the "squamosal" represents the præoperculum). This opercular flap becomes united behind to the skin of the abdomen, the union being first completed on the right side of the neck, while a small opening or respiratory-pore (fig. 358, E *g*) is still preserved on the left side, and allows the tips of the branchiæ to protrude.

With the disappearance of the external gills, a second set of *internal* branchiæ is developed in the form of rows of short lancet-shaped processes upon the branchial arches on each side. The rudiments of the limbs now also appear, the anterior pair being concealed beneath the opercular membrane, so that the hind-limbs are the first to become visible. The lungs are next developed, the pulmonary arteries being at first very small, and the gills being still retained for a time. With the establishment of aerial respiration, the pulmonary arteries increase proportionately in size, and more and more blood is gradually diverted from the gills and carried to the lungs; so that the branchiæ undergo a proportionate decrease in size, and ultimately become atrophied. At the same time, the pulmonary veins, which return the aerated blood from the lungs, increase in size proportionately with their increased work, and ultimately open into a second auricle which is formed at their junction with the heart, this organ thus becoming three-chambered.

The tail of the larva now shortens, and is gradually absorbed; the mouth becomes wider, and is placed at the extremity of the head; the horny beak disappears; teeth are developed on the præmaxillæ, maxillæ, and vomers; and the intestine becomes relatively shorter by remaining stationary while the body goes on growing. Finally, the limbs become fully developed, and the tail is completely absorbed, the animal being thus converted into a small but perfect Frog (fig. 357, 9).

Those Amphibians which retain their larval branchiæ throughout life are said to be "perennibranchiate," and in such forms it is always the *external* gills which persist. On the other hand, those Amphibians which do not retain their branchiæ in adult life are said to be "caducibranchiate." All the perennibranchiate Amphibians, and many of the caducibranchiate types, retain permanently the tail of the larva, and are therefore termed "Tailed" Amphibians (*Urodela*). On the other hand, in the so-called "Tailless" Amphibians (*Anoura*), the larval tail is completely absorbed. In a few cases (*e.g.*, *Hylodes*) the metamorphosis is evanescent; and in other cases (as in *Pipa*, *Nototrema*, and the Alpine Salamander), though a metamorphosis takes place, the branchiæ are shed before the young animal begins to lead a free existence.

The Amphibians are almost universally distributed over the world. The perennibranchiate forms are inhabitants of fresh waters, while the caducibranchiate forms are largely, or in some cases wholly, terrestrial animals—many, however, spending part of their life in water. No Amphibians inhabit the sea.

As regards their *distribution in time*, the extinct group of the Labyrinthodonts is largely represented in the Carboniferous and Permian rocks, and disappears in the Trias. The *Anoura* are not represented in rocks older than the Tertiary period; and, with doubtful exceptions, the same is true of the Urodelans.

The class of the Amphibia is divided into the three living orders of the *Ophiomorpha* (Cæcilians), the *Urodela* (Tailed Amphibians), and the *Anoura* (Frogs and Toads), to which must be added the series of extinct Amphibians which have been usually grouped together under the name of "Labyrinthodonts."

CHAPTER LIII.

ORDERS OF AMPHIBIANS.

ORDER I. OPHIOMORPHA (= *Gymnophiona*, Huxley).—This order comprises the animals which are commonly called "Cæcilians," characterised by their *serpentiform or vermiform bodies, without traces of limbs, and with the cloacal aperture terminal, or nearly so. The adult shows no traces of gills or gill-clefts; the integument has small cycloid scales embedded in it, and the vertebræ are amphicœlous.*

The Cæcilians (fig. 359) are singular worm-like animals, which are found in various tropical countries, burrowing in marshy ground, sometimes reaching a couple of feet or more in length, and somewhat resembling gigantic earth-worms. The skin is annulated, and there is an exoskeleton of small cycloid scales arranged in transverse rings. The notochord is partly persistent, but vertebral segmentation takes place, the vertebræ being amphicœlous, and resembling those of a Bony Fish. The skull is ossified, and has two occipital condyles. Limbs and their arches are absent, but there are well-developed ribs. The maxillæ and palatine bones carry small recurved teeth, and the animal is carnivorous, feeding on

worms and insects. The eyes are rudimentary, and are covered by the skin. The adult possesses lungs; and there are no traces of gills or gill-slits.

The development of the Cæcilians is still imperfectly known. Some forms are ovo-viviparous (*Cæcilia*); others (*Epicrium*) are oviparous. In some species of *Cæcilia* the larvæ possess a gill-slit on each side, leading down

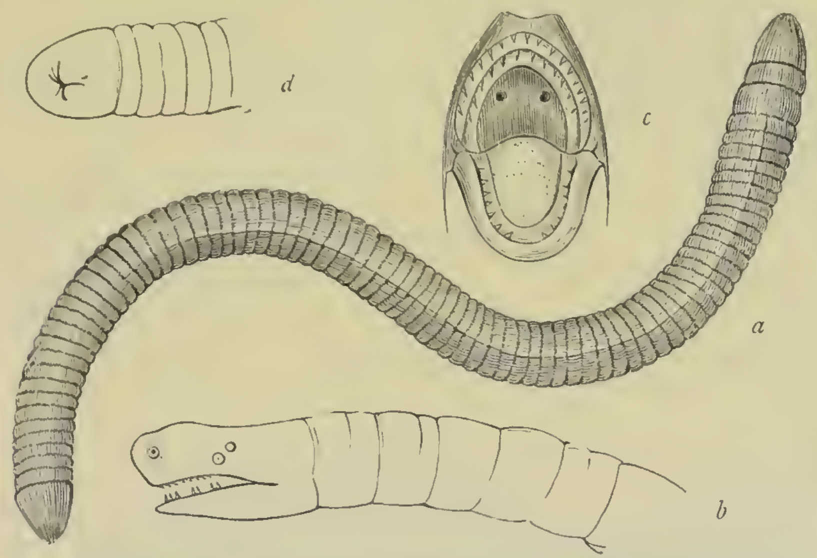

Fig. 359.—Ophiomorpha. *a Siphonops annulatus*, one of the Cæcilians, much reduced; *b* Head; *c* Mouth, showing the tongue, teeth, and internal openings of the nostrils; *d* Tail and cloacal aperture. (After Dumeril and Bibron).

to internal gills. In another species of the same genus (*C. compressicauda*) there is no gill-slit in the larva, but the neck carries vesicular structures believed to be of the nature of external branchiæ. In *Epicrium glutinosum* the embryo prior to its emergence from the egg possesses external branchiæ, which are shed before hatching. After leaving the egg, the larva lives in water, and then breathes by means of gill-slits, which ultimately disappear, the animal then becoming terrestrial.

As regards their distribution in space, the species of *Cæcilia* are found in India, Africa, and South America; *Siphonops* and *Rhinatrema* are exclusively Neotropical; and *Epicrium* is exclusively Asiatic. Upon the whole, the Cæcilians should probably be regarded as a peculiarly modified group of the *Urodela*.

ORDER II. URODELA (= *Ichthyomorpha*, Owen).—This order is commonly spoken of collectively as that of the "Tailed" Amphibians, from the fact that the larval tail is always retained in the adult. The *Urodela* are characterised by having the *skin naked, and destitute of any exoskeleton. The body is elongated posteriorly to form a compressed or cylindrical tail,*

which is permanently retained throughout life. The dorsal vertebræ are biconcave (amphicœlous), or concave behind and convex in front (opisthocœlous), and they have short ribs attached to the transverse processes. The bones of the fore-arm (radius and ulna) on the one hand, and those of the shank (tibia and fibula) on the other, are not anchylosed to form single bones.

In one section of the *Urodela*—hence called *Perennibranchiata*—the gills of the larva persist throughout life, in the form of three plume-like appendages on each side of the neck (fig. 360, A and C), as seen in the *Siren* and *Menobranchus*.

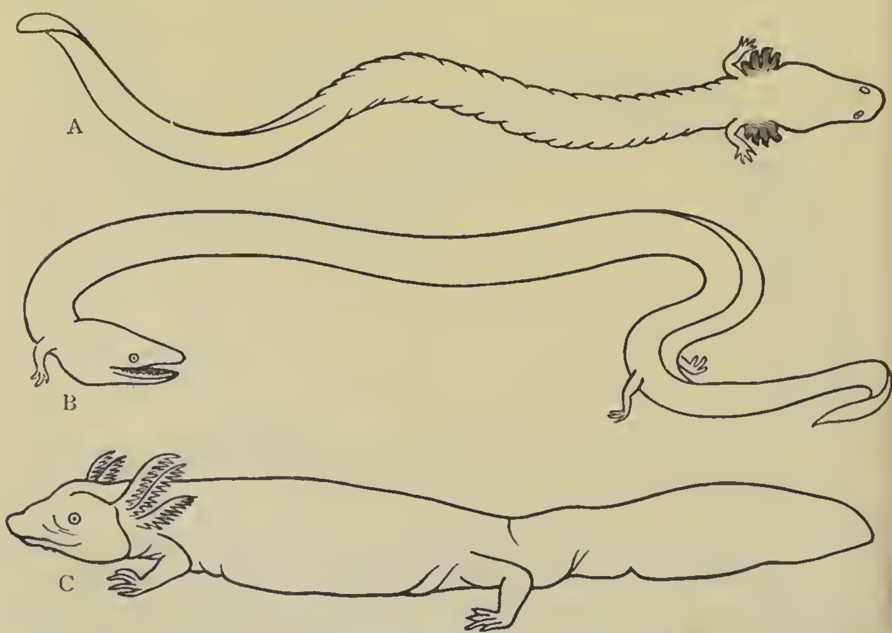

Fig. 360.—Tailed Amphibians. A, *Siren lacertina*; B, *Amphiuma*, showing the four minute limbs; C, *Menobranchus maculatus*. (After Mivart.)

In a second section, termed *Derotremata*, comprising genera such as *Amphiuma* and *Menopoma*, the larval gills disappear, but the gill-slits are retained by the adult. In a third section (*Myctodera*), comprising the various Salamandroids, the perfect adult is destitute of both gills and gill-slits.

Among the *Perennibranchiata*, the *Siren* or Mud-eel (fig. 360, A) is remarkable for the total absence of hind-limbs and of the pelvic arches. There are weak fore-legs, with four or three toes in different species. The *Siren lacertina* grows to a length of about a yard, and is found in the swamps of the southern United States. Another remarkable form is the *Proteus anguinus* of the subterranean waters of Carniola and Dalmatia, in which both pairs of limbs are present, both being short and weak, the anterior having three toes and the posterior two. The eyes in *Proteus* are extremely minute. The neck has three gill-plumes on each side and two

gill-clefts; and the animal grows to the length of about a foot. A third well-known form is the "Mud-puppy" (*Menobranchus* or *Necturus lateralis*) of the fresh waters of the United States. It reaches a couple of feet in length, and all its feet are four-toed.

Forming a transition between the Perennibranchiate Urodelans and the Salamandroids is the group of the *Derotremata*, in which the gill-slits are persistent, though the gills themselves disappear. To this group belong the "Congo-snakes" (*Amphiuma*, fig. 360, B), in which the body is long, and both pairs of limbs are present, each terminating in three toes. The only known species of *Amphiuma* is found in the fresh waters of the Southern United States. Another North American type is the genus *Menopoma*, the only known species of which grows to a length of about a couple of feet. Related to the preceding is the genus *Cryptobranchus* (*Sieboldia*), comprising the Giant Salamanders of Japan and China. These reach a length of between three and four feet, and it is probable that the great *Andrias* of the Miocene Tertiary should be placed in the vicinity of this genus.

Lastly, we have the group of the Salamandroids (*Myctodera*), in which the adult is destitute of both gills and gill-slits. The three most typical groups of this section are the Newts (*Triton*, &c.), the Land-salamanders (*Salamandra*, &c.), and the *Amblystomæ*. The Water-salamanders, or Newts and Efts, are lizard-like in shape, with a vertically-compressed swimming-tail (fig. 361). The males are commonly provided with a dorsal

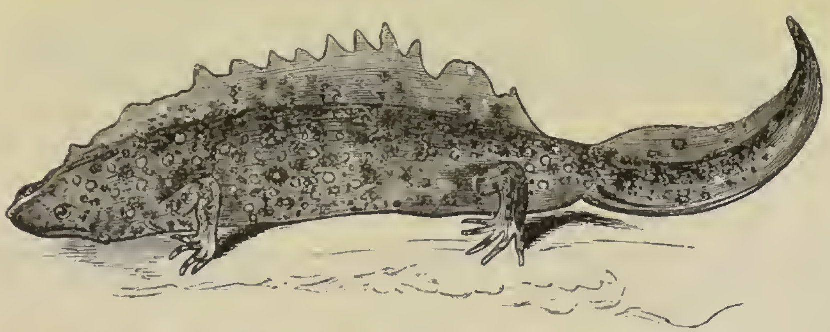

Fig. 361.—Great Water-newt (*Triton cristatus*). (After Bell.)

integumentary crest at the breeding season. The skin is smooth or warty; and the fore-feet have four toes, while the hind-feet are five-toed. The vertebræ are opisthocœlous. All the Water-salamanders are Palæarctic or Nearctic, common British species being the Great Water-newt (*Triton cristatus*) and the Smooth Newt (*Lissotriton punctatus*). The Water-salamanders are oviparous, and the larvæ live in water. The advanced larvæ differ from the tadpoles of the Frog in the fact that the fore-limbs appear externally before the hind-limbs.

The true Land-salamanders, like the Newts, are lizard-like in shape, but they have comparatively thick bodies, and the tail is rounded instead of being compressed. The skin is glandular, and may be smooth or warty. The two known species of the genus *Salamandra* itself are confined to the Palæarctic province, one being the common Spotted Salamander (*S. maculosa*) of Europe and North Africa, and the other the Black Salamander (*S. atra*) of the elevated mountain districts of Central Europe. In the former species, the young, on leaving the mother, have external gills, and are deposited in water. In *S. atra*, on the other hand, only two embryos are hatched at a time, and these are retained within the uterine dilatations

of the oviducts until development is far advanced. While thus retained within the body of the mother, the embryos have extraordinarily long external gills ; but they do not leave the mother until these are completely lost, so that they start external life as genuine terrestrial animals.

Lastly, the genus *Amblystoma* comprises Newt-like Amphibians, all the certainly known species of which—about twenty in number—inhabit the United States and Mexico. In their fully-developed condition the species of *Amblystoma* are terrestrial in habit, and feed upon insects ; but they pass, in some cases at any rate, through a remarkable metamorphosis, which has only become fully known of late years. Naturalists have, namely, been long acquainted with certain singular perennibranchiate Amphibians which inhabit lakes in Western North America and Mexico, and which have usually been known under the name of "Axolotls" (fig. 362). Not only

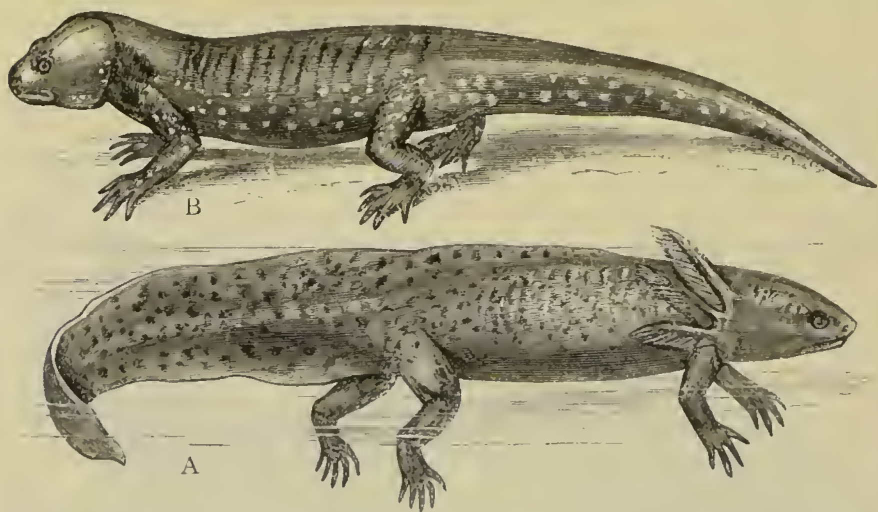

Fig. 362.—The Mexican Axolotl (*Siredon pisciforme*), reduced in size. A, With its gills; B, When its gills have disappeared and it has become an *Amblystoma*. (After Dumeril.)

do the Axolotls entirely resemble the ordinary perennibranchiate Urodelans in the possession of three gill-tufts on each side of the neck, but they have fully-developed reproductive organs, and give rise therefore to new individuals by a true generative process. No doubt, therefore, was felt as to the fact that the Axolotls were genuinely adult or mature, and the genus *Siredon* was created for their reception. It was however shown, more than twenty years ago, that under certain circumstances the common Mexican Axolotl (*Siredon pisciforme*), when kept in domestication, might lose its gills and become caducibranchiate. It was further found that the loss of the gills was accompanied by other marked external and internal changes. Not only did the animal now become terrestrial, and abandon its former aquatic life, but it lost its dorsal and caudal fin-crest, its tail became round instead of being compressed, and it underwent other remarkable changes as regards its dentition, its skeleton, and its external coloration. The Axolotl, in fact, becomes converted into an *Amblystoma*. This change has not been observed to take place in the Mexican Axolotl in Mexico itself; but it has been found to occur in this species in other localities (Wyoming and Utah), in a state of nature. Moreover, it has been shown that the *Siredon lichenoides*, a common Axolotl of the mountain-lakes of the Western United States, becomes changed into a species of

Amblystoma (*A. mavortium*) while in its own natural habitat. In the case of this species many individuals pass towards the end of summer into the *Amblystoma* condition, losing their gill-tufts, and becoming terrestrial in habit; while a still larger number persist in the *Siredon* stage, retaining their gills, and breeding freely. We have, therefore, in the case of these species of *Amblystoma*, the highly remarkable fact of the existence of tailed Amphibians in two sexual conditions. In the one condition (*Siredon* stage) the animal is so far larval that it retains its gill-tufts, but at the same time has the power of reproduction. In the second condition (*Amblystoma* stage) it has lost its gills, and its general organisation has become otherwise variously modified. Remarkable as is the fact that *Amblystoma* should have the power of reproduction while still in the larval condition, it is a fact which does not stand absolutely alone; since some of the Water-salamanders (*Triton alpestris* and *Lissotriton punctatus*) have been found to be sometimes sexually perfect, while still retaining their larval characters.

ORDER III. ANOURA OR BATRACHIA (*Theriomorpha*, Owen).—This order comprises the Frogs and the Toads, and is characterised by the fact that *the larvæ possess external and internal gills, gill-slits, and a tail, while all these structures are wanting in the adult. The præsacral vertebræ never exceed nine in number, and almost always have procœlous centra. Both pairs of limbs are present, and the radius and ulna in the fore-limb and tibia and fibula in the hind-limb are anchylosed to form single bones. The hind-limbs are generally longer than the fore-limbs, and the manus has five digits.*

The metamorphosis in the *Anoura* is more complete than in any other group of the Amphibians, and has previously been briefly sketched (see p. 593). The larvæ or "tadpoles" mostly inhabit water, and are furnished first with external and subsequently with internal gills. The hind-limbs of the tadpoles become visible sooner than the fore-limbs, as the latter are at first covered by the opercular flap which grows over the gills. In some cases (*Nototrema* and *Notodelphys*) the females are provided with brood-pouches or saccular involutions of the dorsal integument, within which the earlier stages of development are passed. In the case of one of the species of *Hylodes*, again, there can hardly be said to be any metamorphosis, the branchiæ being absent or evanescent, while the anterior and posterior limbs are developed contemporaneously, and the tail is absorbed within the first day after emergence from the egg.

In the adult *Anoura*, respiration is purely aerial, and is carried on by means of lungs, which are, comparatively speaking, well developed. As there are no movable ribs by which the thoracic cavity can be expanded, the process of respiration is somewhat peculiar. The animal first closes its mouth, and fills the whole buccal cavity with air taken in through the

nostrils. The posterior nares are then closed, and by the contraction of the muscles of the cheeks and pharynx the inspired air is forcibly driven into the windpipe through the open glottis. The process, in fact, is one of swallowing; and it is possible to suffocate a frog simply by holding its mouth open, and thereby preventing the performance of the above-mentioned actions. There can be no doubt, also, that the skin in these animals plays a very important part in the aeration of the blood, and that the frogs especially can carry on their respiration cutaneously, without the assistance of the lungs, for a very lengthened period. This undoubted fact, however, should not lead to any credence being given to the often-repeated stories of the occurrence of frogs and toads in cavities in solid rock, no authenticated instance of such a phenomenon being as yet known to science.

Fig. 363.—The Common Frog (*Rana temporaria*).

The order *Anoura* may be divided in accordance with the structure of the tongue into the three sections of the *Aglossa*, *Opisthoglossa*, and *Proteroglossa*. These sections are of an extremely different value, the first comprising only the two genera *Pipa* and *Dactylethra*, and the last including only the single genus *Rhinophrynus*, while all the other forms of the order are contained in the *Opisthoglossa*.

In the section of the *Aglossa* a tongue is not developed. The best-known genus is *Pipa*, comprising only the "Surinam Toad" (*P. Americana*), which inhabits Guiana. In this curious Amphibian the dorsal integument of the female becomes greatly thickened at the breeding season, and the impregnated eggs are placed by the male in cell-like cavities in this soft integument. In these cavities the eggs are hatched, the larval

stages of development being completed before the young are liberated to lead an independent life. The only other Aglossate genus is *Dactylethra*, which differs from *Pipa* in the fact that the præmaxillæ and maxillæ bear small teeth, whereas the latter is toothless. The three inner toes of the pes are furnished with nails, as is the case in no Amphibian save *Salamandra unguiculata* among the Urodelans. The few known species of *Dactylethra* are confined to Africa, south of the Sahara.

The section *Opisthoglossa* comprises those forms in which the tongue is fixed in front, and free behind, and includes all the ordinary types of the order. Here only some of the principal groups can be noted, and that in the briefest manner. Of the forms which are usually called "Frogs," the family of the *Ranidæ* is the most familiar, and comprises a number of Anourans, in which the upper jaw carries small teeth, the digits are pointed at their ends, and the hind toes are webbed. The genus *Rana* itself comprises nearly eighty species, and has an almost world-wide distribution. No species occur in the West Indies, the northern parts of North America, or the continent of Australia, the only known species inhabiting the Australian province being found in New Guinea. The common Grass Frog (*Rana temporaria*) and the Edible Frog (*R. esculenta*) have an enormously wide range. In the Grass Frog (fig. 363) the manus has four visible fingers, the thumb being rudimentary. In the males the innermost digit of the hand has its inner edge thickened at the breeding season. The pes has five complete toes, of which the fourth is the longest, and the digits are united by a web. On the inner side of the hallux is a little horny prominence or "calcar." The hind-leg of the Frog looks as if it were made up of four segments, the third segment being really the greatly elongated calcaneum and astragalus, which become united by their ends. The Edible Frog differs, among other characters, from the Grass Frog in the fact that the males possess "vocal sacs"—*i.e.*, dilated sacs placed on each side of the head behind the angle of the lower jaw, and opening into the mouth, their function being that of increasing the resonance of the voice. The largest species of the genus *Rana* is the great Bull-frog (*R. pipiens*) of North America.

Very similar to the typical Frogs in most respects are the *Cystignathidæ*, in which, however, the toes of the hind feet are not webbed. Most of the forms of this group are South American. In the *Bombinatoridæ*, again, the organ of hearing is imperfectly developed, or may even be wanting. The genus *Bombinator* itself is represented by a single species in Central Europe and Italy, and is remarkable in the fact that the centra of the dorsal vertebræ are opisthocœlous.

The great family of the *Bufonidæ* comprises most of the forms which are usually called "Toads," in which the digits are pointed, but there are no præmaxillary or maxillary teeth. In the genus *Bufo* the toes of the hind-limb are partially or completely webbed, and the hand has four free digits. On each side of the neck, behind the eye, is a gland ("parotid gland") which secretes an acrid fluid. Nearly a hundred species of *Bufo* are known, and have an almost universal distribution; though only three species are found in Europe. The commonest of these is the Common Toad (*B. vulgaris*) which is found over Europe and Asia, and lives up to heights of 10,000 feet above the sea-level. A rarer British species is the Natterjack Toad (*Bufo calamita*). The third European species (*B. variabilis*) does not occur in Britain.

The remaining types of the Opisthoglossate Anourans have the extremities of the toes expanded to form sucking-discs, and are usually spoken of as "Tree-Frogs." They differ in the form of their toes from the typical Frogs, but most of them agree with these, and differ from the Toads, in

having præmaxillary and maxillary teeth. The typical family is that of the *Hylidæ*, the genus *Hyla* itself being represented by nearly ninety species, the majority of which are found in South America and in the Australian province. The only European species is the widely distributed little green Tree-frog (*Hyla arborea*).

Lastly, the section of the *Proteroglossa* is characterised by the fact that the tongue is fixed behind and free in front, while the upper jaw is edentulous. This section comprises the single species *Rhinophrynus dorsalis* of Mexico.

ORDER IV. STEGOCEPHALA.—Under this name we may group together a large number of extinct Amphibians which are usually spoken of as "Labyrinthodonts." This name is in allusion to the peculiarly complex structure of their teeth, the parietes of which are folded inwards in a labyrinthine manner, as shown by transverse sections (fig. 364). The

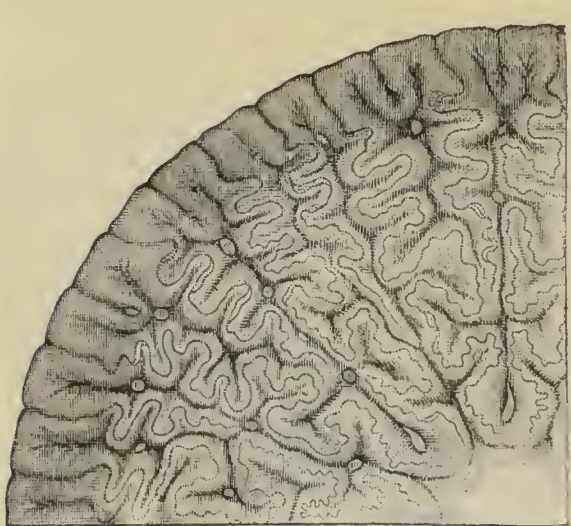

Fig. 364.—Section of the tooth of *Labyrinthodon* (*Mastodonsaurus*) *Jægeri*, showing the microscopic structure. Greatly enlarged. Trias.

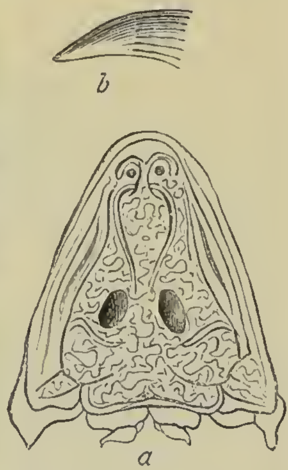

Fig. 365.—*a* Skull of *Labyrinthodon Jægeri*, much reduced in size; *b* Tooth of the same. Trias. Würtemberg.

skull (fig. 365) was broad and flattened, and was in many cases covered with a sort of helmet formed of hard and polished bony plates, which are commonly sculptured externally, or exhibit peculiar symmetrical grooves. The skull is united to the vertebral column by two occipital condyles. Another extraordinary feature is, that the abdomen was protected by an exoskeleton formed of oval plates of bone. The notochord was more or less largely persistent, most forms possessing amphicœlous vertebræ. In most forms the vertebral column is prolonged into a long caudal region. In *Archegosaurus*, branchial arches seem to have been present, though whether they were persistent or not is uncertain.

The condition of the limbs in the Labyrinthodonts varied greatly. In *Ophiderpeton*, and in a number of other forms, no limbs appear to have been developed. In the majority of cases, however, both pairs of limbs were present, the hind-limbs being larger than the fore-limbs. This is well shown by the footprints of Labyrinthodonts, which have been commonly preserved, and which show (fig. 366) a series of alternate pairs

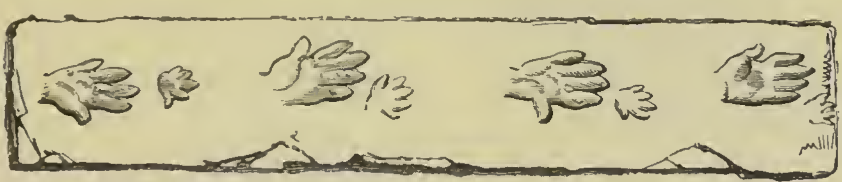

Fig. 366.—Footprints of a Labyrinthodont (*Cheirotherium*).

of hand-shaped impressions, the hinder print of each pair being much larger than the one in front. These footprints are of common occurrence in the Triassic rocks of Europe; and it being at first unknown by what animal they had been produced, the genus *Cheirotherium* was founded for their reception.

The Labyrinthodonts vary also greatly in size, some forms being of moderate dimensions, while others must have been colossal. Thus, the skull of *Labyrinthodon* (*Mastodonsaurus*) *Jægeri* is upwards of three feet in length.

As regards their distribution in time, the Labyrinthodonts are not only extinct, but they are only known as occurring in the Carboniferous, Permian, and Triassic rocks. They attain their maximum development in the Carboniferous rocks, but the largest forms occur in the Trias. It may be added that it has been shown that a large number of Palæozoic Amphibians which have been spoken of under the general title of "Labyrinthodonts" have no "labyrinthine" pattern in their teeth, and the precise place which many of these forms should occupy is still uncertain.

LITERATURE.

[In addition to many of the systematic works enumerated in the list of treatises relating to the Vertebrata generally (p. 531), the student may consult the following as to the living and extinct Amphibians:—]

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DIVISION II.—SAUROPSIDA.

CHAPTER LIV.

CLASS III.—REPTILIA.

The classes of the Reptiles and Birds are in many fundamental points as regards their organisation closely connected with one another, and they have been grouped together by Professor Huxley in the single division of the *Sauropsida*. This division is characterised by the fact that the embryo is furnished with an amnion and allantois, and that branchiæ, or water-breathing respiratory organs, are never developed upon any of the visceral arches at any period of life. The red blood-corpuscles are oval in shape, and are furnished with nuclei (fig. 315, *b*, *c*). The skull articulates with the vertebral column by a single occipital condyle. The mandible is complex, being composed of several pieces, and it is attached to the skull by the intervention of a quadrate bone. Lastly, all the *Sauropsida* are oviparous or ovo-viviparous.

The above being the common characters of the *Sauropsida*, the *Reptilia* are distinguished from the *Aves* by the following characters:—

The blood in Reptiles is cold—that is to say, slightly warmer than the external medium—owing in part to the fact that the pulmonary and systemic circulations are always directly connected together, either within the heart or in its immediate neighbourhood, so that the body is supplied with a mixture of venous and arterial blood, in place of pure arterial blood alone. There are never fewer than two aortic arches present. The terminations of the bronchi at the surface of the lung are closed, and do not communicate with air-sacs, placed in different parts of the body. When the epidermis develops horny structures, these are in the form of horny plates or scales, and never in the form of feathers. The fore-limbs are formed for

various purposes, including in some cases even flight, but they are never constructed upon the type of the "wing" of Birds. Lastly, whilst the ankle-joint is placed between the distal and proximal portions of the tarsus, the tarsal and metatarsal bones of the hind-limb are never anchylosed into a single bone.

The shape of the body in the Reptiles is very variable, but with the exception of the Tortoises and Turtles, they are mostly of an elongated form, provided with a longer or shorter tail, and either limbless or, more usually, provided with two pairs of variously constructed limbs.

The *exoskeleton* of Reptiles usually has the form of horny scales or scutes, which are formed by a hardening of the epidermis, but are not produced within follicles. Moreover, the dermis always takes part in the formation of the scales. In some cases, as in Chelonians and Crocodilians, the dermis becomes more or less extensively hardened by ossification, and such forms are grouped together under the name of *Loricata*, whilst those types which have epidermic scales, without dermal bones, have been spoken of as the *Squamata*.

As regards the *endoskeleton*, the notochord always shows vertebral segmentation, and is generally more or less completely ossified. In a few forms (Geckos, *Sphenodon*, and certain extinct Reptiles), the vertebræ are amphicœlous, but they are usually procœlous. Ribs are present, and are often numerous, but a sternum may be absent (in Chelonians, Ophidians, and a few Lizards). The skull is ossified, and there is a single occipital condyle, often with a trifid articulating surface, carried upon the ossified basioccipital and exoccipital bones. The mandible (fig. 311) is complex, each ramus consisting of several pieces, and it is united to the skull by means of a quadrate bone (fig. 367), which is firmly united with the skull in Chelonians and Crocodilians, but is more or less movable in Lizards and Ophidians. Teeth are absent in Chelonians and in some extinct Reptiles, but are present in the other members of the class. They are mostly adapted for holding the prey, and not for mastication, and they are in general anchylosed with the bones which support them, but are fixed in sockets in Crocodiles and in some extinct types. The bones which usually carry teeth are the mandible and maxillæ, with or without the præmaxillæ; but in Snakes the pterygoid and palatine bones carry teeth, as do the former in many of the Lizards.

Pectoral limbs and their arches are absent in the Snakes, as are the pelvic limbs also with but partial exception. Limbs are also wanting in the serpentiform Lizards, though in these

cases the pectoral and pelvic arches are more or less completely represented. In Reptiles generally both pairs of limbs are present; but the form of the manus and pes varies much. When the manus is present, it never has less than four digits, and the three innermost of these at least are provided with

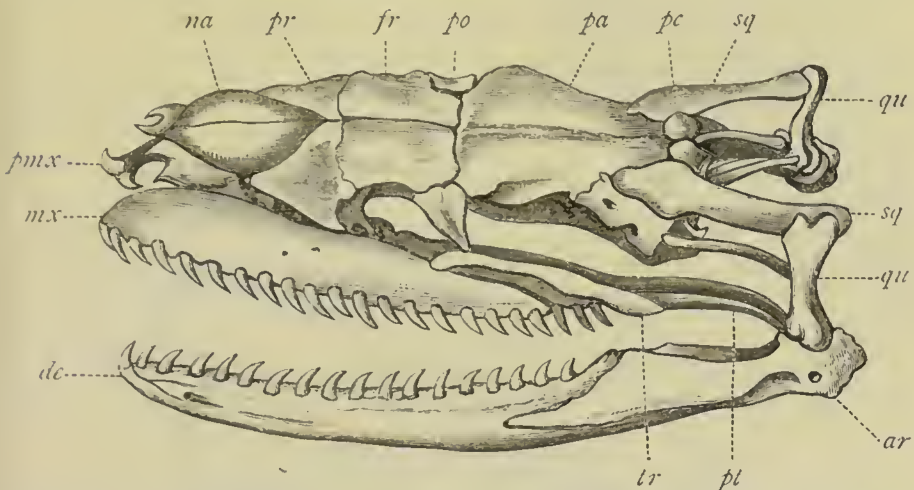

Fig. 367.—Skull of a Constricting Serpent (*Python*). *dc* Dentary portion of the mandible; *ar* Articular portion of the mandible; *qu* Quadrate bone; *sq* Squamosal; *pc* Proötic; *pa* Parietal; *po* Post-frontal; *fr* Frontal; *pr* Præfrontal; *na* Nasal; *pmx* Præmaxillary; *mx* Maxillary; *tr* Transverse bone; *pt* Pterygoid.

claws. The ankle-joint is placed between the proximal and distal rows of tarsal bones, and not between the proximal tarsal bones and the tibia. Moreover, the metatarsal bones are never united with one another and with the distal row of tarsal bones, as occurs in Birds generally. There are never fewer than three digits in the pes.

The *digestive system* presents few points of interest. The alimentary canal consists of a gullet, stomach, and small and large intestine, and a liver and pancreas are present. The rectum opens into a terminal dilatation or "cloaca," which also receives the ducts of the urinary and reproductive organs. The cloacal aperture is longitudinal or rounded in Chelonians and Crocodilians, but is transverse in the Snakes and the Lizards.

As regards their *circulatory system*, the blood in all Reptiles is cold, and the red corpuscles of the blood are oval and nucleated. The heart consists of two completely separated auricles (a right and left auricle), and of an incompletely divided common ventricle (fig. 368). In the *Crocodilia* alone is the septum between the ventricles a perfect one, and in

these there is still a communication between the left and right sides of the heart by means of an aperture which connects the two great aortic trunks at a point just above their origin from their respective ventricles. In the most typical condition of parts (fig. 368), the circulation in the Reptiles is as follows: The venous blood returned from the body is poured into the right auricle by the great veins (two superior venæ cavæ and one inferior vena cava), a "sinus venosus" being generally formed at the point of junction of these. The arterial blood

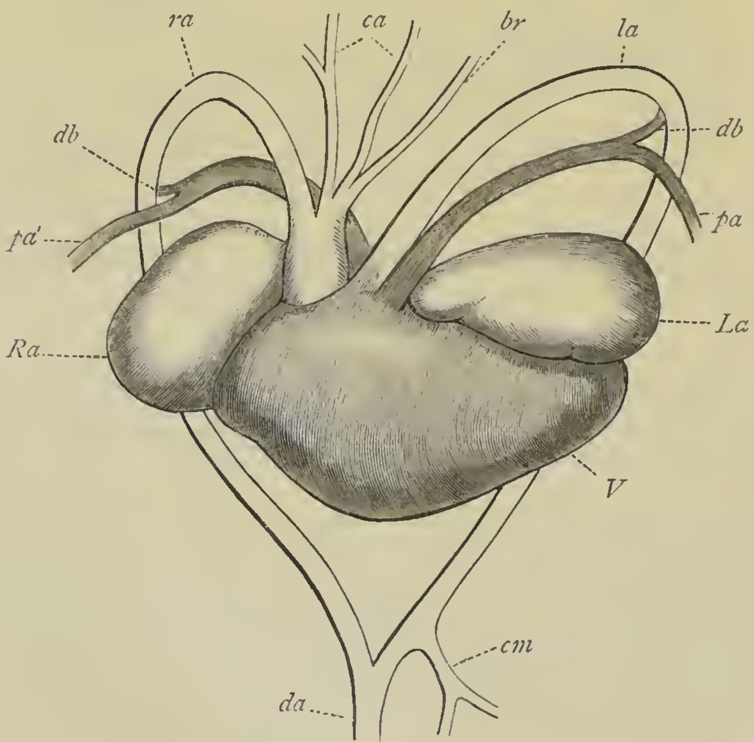

Fig. 368.—Plan of the heart and great vessels of a Chelonian, the venæ cavæ and pulmonary veins being omitted. *V* Common ventricle; *Ra* Right auricle; *La* Left auricle; *ra* Right aorta, giving off the carotid trunks (*ca*); *la* Left aorta, giving off the cœliaco-mesenteric artery (*cm*), and joining the right aorta to form the descending aorta (*da*); *pa* Left pulmonary artery; *pa'* Right pulmonary artery; *db Ductus Botalli*; *br* Brachial artery.

returned from the lungs is poured by one or two pulmonary veins into the left auricle. The common ventricle should thus, in theory, contain a mixture of arterial and venous blood; and it undoubtedly does do so in actual fact to a greater or less extent. There are, however, arrangements, in the partial division of the ventricle into a right and left half, and otherwise, by which the venous and arterial streams are kept more or less largely separate, and are prevented from becom-

ing completely mixed in the ventricle. The ventricle gives off three great arterial trunks. One of these (fig. 368, *ra*) is the right aorta (or brachio-cephalic aorta), which, though placed on the right side, really has its origin from the left side of the ventricle. The second is the left aorta (*la*), which springs in reality from the right side of the ventricle; so that the two aortæ cross each other more or less clearly at their points of origin from the ventricle. The third great trunk is the pulmonary artery (*pa*), which carries venous blood to the lungs. The right aorta is supplied principally with pure arterial blood, and it gives origin to the great carotid trunks (fig. 368, *ca*) which supply the head. The anterior part of the body is thus supplied with arterial blood. The left aorta, springing as it does from the right half of the ventricle, carries mixed blood, and it gives off no branches to the anterior part of the body. It gives origin, however, to the great cœliaco-mesenteric artery (fig. 368, *cm*). The right and left aortæ ultimately join with one another, either by fusion or by a connecting-branch, to form the descending aorta (fig. 368, *da*). As the blood in the left aorta is not pure arterial blood, it follows that the trunk and hinder extremities are supplied with a fluid which is more or less largely an intermixture of arterial with venous blood. The pulmonary artery is supplied principally with venous blood, which is distributed to the lungs. In the Chelonians there exists a connecting-vessel (ductus Botalli, fig. 368, *db*) between the pulmonary arteries and the systemic aorta on each side.

In the Crocodilians, alone of all Reptiles, the partition between the right and left halves of the ventricle is complete, so that the right side of the heart is wholly venous and the left side wholly arterial. The right ventricle gives origin to the *left* aorta and to the pulmonary artery, both of which are thus filled with unmixed venous blood. On the other hand, the left ventricle gives off the *right* aorta, which therefore contains arterial blood, which it distributes to the head and anterior extremities through the carotid and subclavian trunks. Though the heart of the Crocodiles is thus completely separated into a right and left half, the intermixture of venous and arterial blood which is so characteristic of the Reptiles takes place in these forms also, though not in the heart itself. The right and left aortæ, carrying respectively arterial and venous blood, are, namely, connected with one another at the point where they cross, just above their origin from the ventricles, by the so-called "foramen Panizzæ." By means of this foramen there is an intermixture of the venous and arterial blood

carried by the left and right aortæ respectively. This arrangement is correlated with the habit of the Crocodilians of drowning their prey under water. Thus when the animal's respiration is impeded by prolonged submersion, and when the right side of the heart consequently tends to become gorged with venous blood, the pressure is relieved by the escape of the venous blood from the left aorta into the right aorta through the foramen Panizzæ. There is, further, as in Reptiles generally, an intermixture of arterial and venous blood in the subvertebral aorta, which is formed by the union of the right and left aortæ, so that the trunk and hind-limbs are supplied with mixed blood.

The *respiratory organs* of Reptiles are lungs, to which air is admitted by a trachea, dilated superiorly into a larynx, and divided inferiorly into bronchial tubes. The lungs are usually capacious sacs, sometimes nearly as simple as in the higher Amphibians, but usually more or less subdivided by internal septa. In the Snakes and the serpentiform Lizards, one lung is much reduced in size, or may be quite rudimentary. In such cases the principal functional lung is long and tubular, and its hinder portion is only an undivided membranous sac, which serves as a reservoir for air.

The *kidneys* are paired, and are situated in the hinder portion of the abdominal cavity, their ducts opening into the "cloaca." A urinary bladder is present in Chelonians and Lizards, but is absent in Snakes and Crocodiles.

The *brain* of Reptiles exhibits a decided advance upon that of Fishes and Amphibians, the cerebral hemispheres being proportionately larger, and extending backwards over the optic thalami, while the optic lobes are relatively reduced in size.

Lastly, the sexes in Reptiles are distinct, and the *generative glands* are paired. The vasa deferentia of the males and the oviducts of the females open by separate apertures into the cloaca. The oviducts are long, sometimes with terminal "uterine" dilatations, and the eggs in their passage through the oviduct acquire a membranous or calcareous shell. Fertilisation is always internal, and the majority of the Reptiles are strictly oviparous, a few forms being ovo-viviparous.

The Reptiles have representatives in almost all regions, but the Crocodilians are exclusively confined to tropical countries. Most of the existing Reptilia are terrestrial, but the Crocodilians and many of the Chelonians are amphibious, while the *Hydrophidæ* and Turtles are essentially aquatic. No existing Reptiles are adapted for flight.

As regards their *distribution in time*, the earliest certain re-

mains of Reptiles are found towards the close of the Palæozoic period, in the Permian rocks. Here we meet with representatives of the Lacertilians, which do not seem to differ in important respects from existing Lizards. The Chelonians make their first undoubted appearance in the Jurassic rocks; while the Crocodilians are found in the still older Triassic deposits. The Snakes, finally, do not appear till the Tertiary period is reached. Not only are all the existing orders of Reptiles represented by extinct forms, but the Secondary rocks have yielded the remains of a very large number of fossil Reptiles which belong to several wholly extinct *orders*, the characters of which will be briefly noticed later on.

CHAPTER LV.

DIVISIONS OF REPTILES.

CHELONIA.

THE class *Reptilia* is divided into the following ten orders, of which the first four are represented by living forms, whilst the remaining six are extinct:—

<table>
<tr><td>1. Chelonia (Tortoises and Turtles).</td><td rowspan="4">Recent.</td></tr>
<tr><td>2. Ophidia (Snakes).</td></tr>
<tr><td>3. Lacertilia (Lizards).</td></tr>
<tr><td>4. Crocodilia (Crocodiles and Alligators).</td></tr>
<tr><td>5. Ichthyopterygia.</td><td rowspan="6">Extinct.</td></tr>
<tr><td>6. Sauropterygia.</td></tr>
<tr><td>7. Anomodontia.</td></tr>
<tr><td>8. Pterosauria.</td></tr>
<tr><td>9. Deinosauria.</td></tr>
<tr><td>10. Theriodontia.</td></tr>
</table>

ORDER I. CHELONIA.—The first order of living Reptiles is that of the *Chelonia*, comprising the Tortoises and Turtles, and distinguished by the following characters: *There is an osseous exoskeleton which is combined with the endoskeleton to form a kind of bony case or box in which the body of the animal is enclosed, and which is covered by a leathery skin, or, more usually, by horny epidermic plates. The dorsal vertebræ, with the exception of the first, are immovably connected together,*

and are devoid of transverse processes. The ribs are greatly expanded (fig. 369), *and are united to one another by sutures, so that the walls of the thoracic cavity are immovable. All the bones of the skull except the lower jaw and the hyoid bone are immovably united together. There are no teeth, and the jaws are encased in horn so as to form a kind of beak. The tongue is thick and fleshy. The heart is three-chambered, the ventricular*

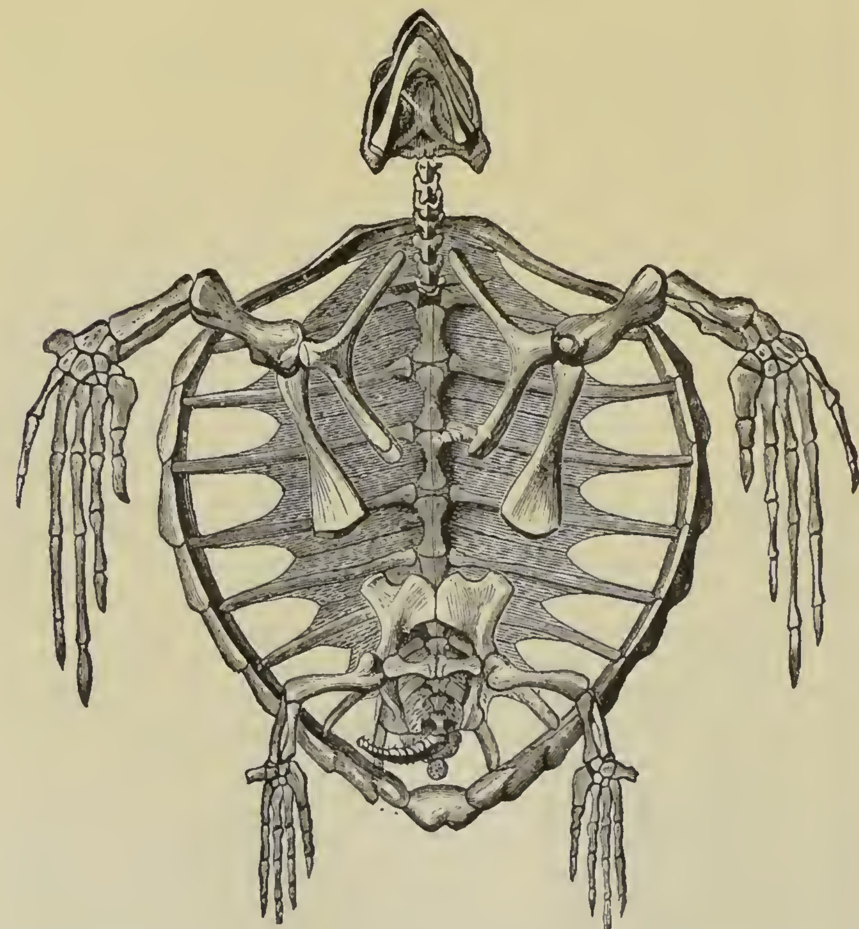

Fig. 369.—Skeleton and carapace of the Loggerhead Turtle (*Chelone caouanna*), viewed from below, the plastron being removed.

septum being imperfect. There is a large urinary bladder, and the anal aperture is longitudinal or circular. The lungs are voluminous, and respiration is by swallowing air, as in the Frogs.

The skull of the Chelonians consists of bones, which, with the exception of the mandible and hyoid, are immovably joined to one another. The pieces which compose each ramus of

the mandible are anchylosed with one another, and the two rami are similarly anchylosed in front. The quadrate bone is immovably fixed to the skull, and is joined to the maxilla by the quadrato-jugal and jugal bones. The temporal fossæ are more or less extensively roofed over by wide lateral extensions of the parietal bones, which join extensions of the postfrontal, jugal, quadrato-jugal, and squamosal bones. There are no teeth, and the edges of the jaws are sheathed in horn, constituting a kind of beak.

The thoracico-abdominal case within which the body of a Chelonian is enclosed (fig. 369) consists of two principal divisions, a superior or dorsal piece, of a more or less convex shape, termed the "carapace," and an inferior or ventral piece, generally flat or concave, called the "plastron." The carapace and plastron are firmly united along their edges, but are excavated in such a way as to leave an opening in front and behind, the anterior serving for the passage of the head and fore-limbs, while the tail and hind-limbs pass through the other. The limbs and tail can usually be withdrawn under the shelter of the case thus formed by the carapace and plastron, and the head is also often similarly retractile.

The carapace or dorsal shield (figs. 370, 371) is composed of the following elements:—

(1.) *The neural spines of all the dorsal vertebræ*, except the first and last, which are flattened out laterally, and form a series of median plates, firmly united with one another by indented sutures, and termed the "neural plates" (fig. 371, *n*). As there are only ten dorsal vertebræ, and as the first and tenth do not enter directly into the composition of the carapace, there are only eight "neural plates," strictly so called. The eighth neural plate is, however, followed by three additional median plates, which have also been generally termed "neural plates," but which do not become directly connected with the vertebræ below.

(2.) The above-mentioned series of median plates is completed in front and behind by unpaired plates, of which the anterior (fig. 370, *nu*) is termed the "nuchal plate," while the posterior one (sometimes wanting) is called the "pygal plate" (fig. 370, *py*).

(3.) The eight proper neural plates are bordered on each side by eight long flattened plates, which are firmly united with the median series, and laterally with each other, by sutures (fig. 370, *c*). These lateral pieces are made up principally of the laterally expanded ribs, the heads of which are joined directly with the vertebræ. To the upper surface of each rib

there is, however, anchylosed a broad dermal plate of bone, which is termed a "costal plate." These costal plates are united with one another laterally by sutures, and become similarly joined at their inner ends with the neural plates (fig. 371, *c'*). In many cases the costal plates are not as long as the ribs, and the latter are too narrow towards their ends to become connected with one another laterally. In such cases there are marginal apertures between the ribs towards their

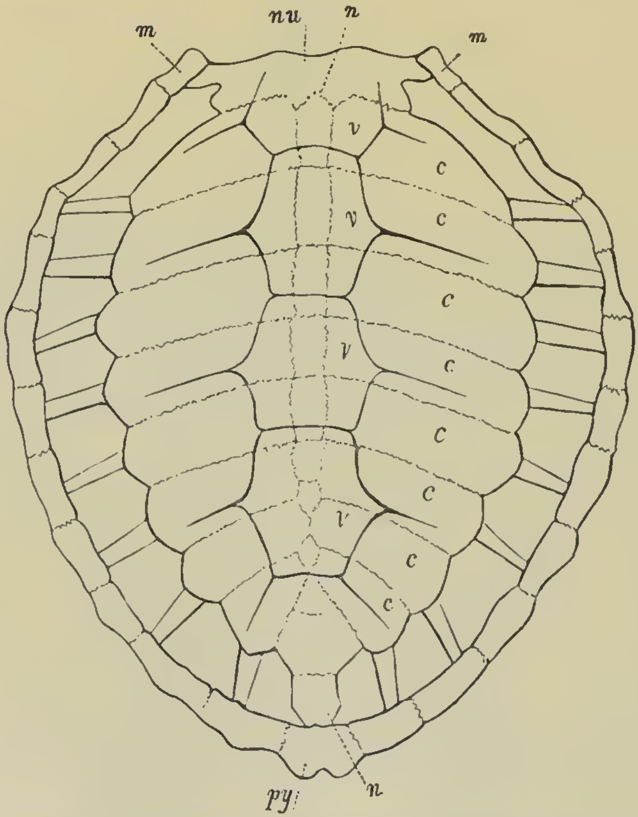

Fig. 370.—Carapace of the Loggerhead Turtle (*Chelone caouanna*), viewed from above (after Owen). In this form, the ribs are separate and free towards their extremities, and the osseous portions of the carapace are indicated by the light lines, while the epidermic plates are marked out by dark lines. *n n* The first and last of the median series of "neural plates"; *c c* The expanded ribs or "costal plates"; *m m* The first "marginal plate" on each side; *nu* Nuchal plate; *py* Pygal plate; *v v* Median series of epidermal plates, or "vertebral scutes."

extremities, and these openings are simply covered by the integuments (figs. 369, 370).

(4.) The margin of the carapace is completed by a peripheral series of bony plates, which are known as the "marginal plates" (fig. 370, 371, *m*), and which are of the nature of dermal ossifications. The "marginal plates," twelve in number on each

side, as a rule, are suturally joined to each other, as also to the nuchal plate in front and the pygal plate behind, while they are connected with the ribs internally.

The plastron or ventral shield (fig. 372) is more or less flattened, and is composed of nine bony pieces, of which eight are

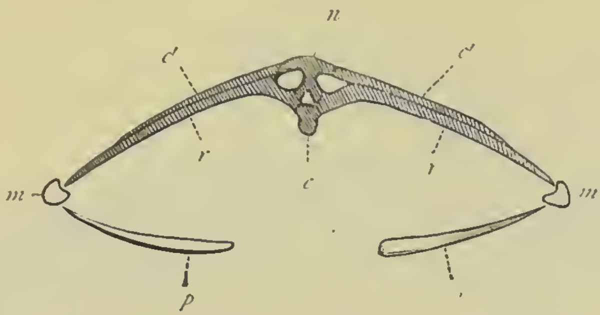

Fig. 371.—Transverse section of the skeleton of *Chelone midas* in the dorsal region. *c* Body of one of the dorsal vertebræ; *n* Expanded spinous process or "neural plate" of the same; *r r* Ribs; *c' c'* "Costal plates"; *m m* Marginal plates; *p p* Lateral elements of the plastron. (After Huxley.)

in pairs, and the ninth is placed anteriorly, and is unpaired. The unpaired plate and the first pair of the paired plates (the "entosternal" and "episternal" plates of Owen) represent an interclavicle and a pair of clavicles. The remaining three pairs of plates are known respectively, from before backwards, as the hyoplastra, hypoplastra, and xiphiplastra (the "hyo-," "hypo-," and "xiphi-sternals" of Owen), and are of the nature of dermal bones, as are also the three anterior plates.

Both the carapace and plastron are covered by a series of horny plates (rarely wanting), which are developed in the epidermis, and which are perfectly distinct from the bones which they cover. As encasing the upper surface of the carapace, these plates (which in some species constitute the "tortoise-shell" of commerce) have a general arrangement conforming with that of the bony plates beneath, though there is no numerical correspondence between the two. Thus the carapace, as we have seen, consists of (1) a median series of "neural" plates developed from the vertebræ; (2) a lateral series of "costal" plates on each side, corresponding with and largely formed by the ribs; and (3) a peripheral series of "marginal" plates (see fig. 370). Similarly, the epidermic plates (fig. 370) are arranged in (1) a median, "vertebral," or "neural" series; (2) a lateral series on each side, of "costal" scutes; and (3) a series of "marginal" scutes. The "vertebral" scutes, however, are only *five* in number; and each series of "costal" scutes consists only of *four* pieces, so that

the number of epidermic plates is much smaller than that of the bony plates beneath. The "marginal" scutes, on the other hand, correspond in number with the "marginal plates" beneath them. They are, therefore, twenty-four or twenty-six

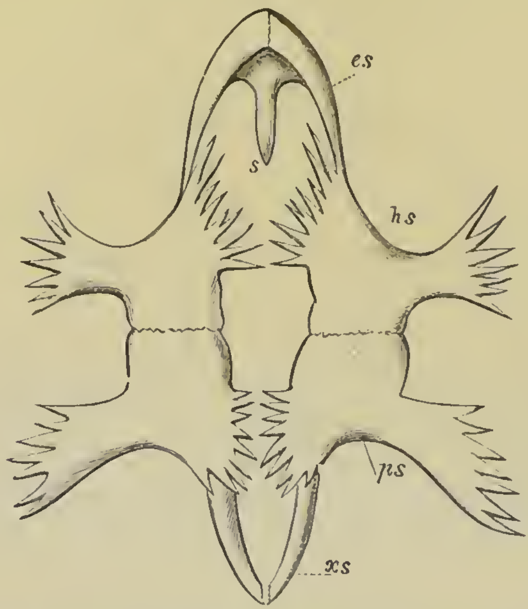

Fig. 372.—Bones of the plastron of the Loggerhead Turtle (*Chelone caouanna*). *s* Entoplastron; *es* Epiplastron; *hs* Hyoplastron; *ps* Hypoplastron; *xs* Xiphiplastron. (After Owen.)

in number, the anterior scute in the middle line being distinguished by the epithet of "nuchal," while the corresponding scute behind is termed "pygal."

Both pairs of limbs are present in the Chelonians, and the pectoral and pelvic arches are within the carapace, to which, to begin with, they are external, only becoming enclosed in the process of growth. The scapula is a rod-like bone, the upper end of which is connected with the transverse process of the first dorsal vertebra. Fused with the scapula is a precoracoid bone ("acromion"), which is connected inferiorly with the unpaired "entoplastral" plate of the plastron. The pectoral arch is completed by a large and separate coracoid bone.

The Chelonians are divided into five principal families, as follows :—

(1.) *Cheloniidæ.*—This family includes the true Turtles, characterised by the depressed and flattened form of the carapace, and the adaptation of the limbs to act as swimming paddles. The digits in both pairs of limbs are undistinguishably united by the skin, and only one or two, or none of them have nails, while the hind-limbs are directed backwards in the axis of the body, and the anterior limbs are much the longest. The Turtles

are all inhabitants of warm seas, and only visit land for the purpose of depositing their eggs in holes which they scrape in the sand. The best-known species are the "Edible" or Green Turtle (*Chelone midas*), the Loggerhead Turtle (*Chelone caouanna*), the Hawk's-bill Turtle (*C. imbricata*), and the Leathery Turtle (*Sphargis coriacea*). The Green Turtle is largely imported into this country as a delicacy, and occurs abundantly in various parts of the Atlantic and Indian Oceans. The Hawk's-bill Turtle

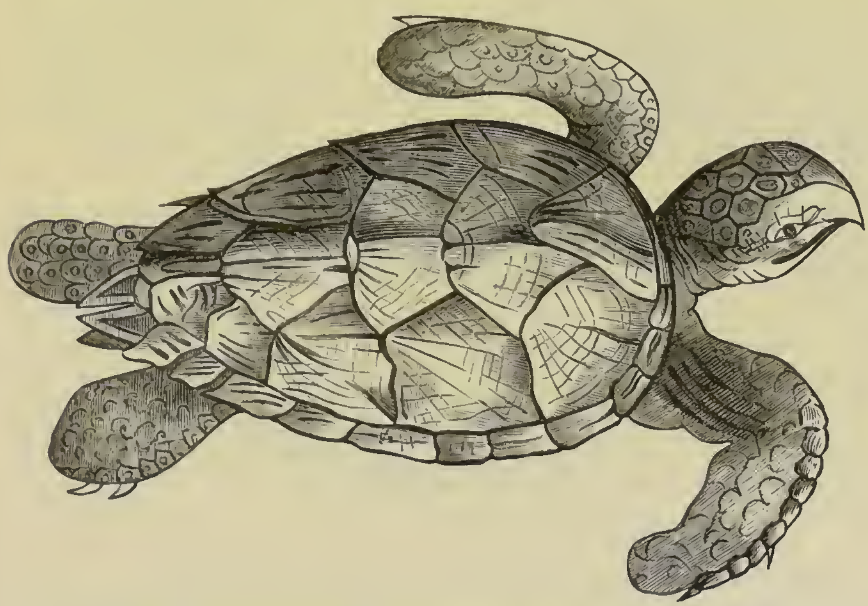

Fig. 373.—Hawk's-bill Turtle (*Chelone imbricata*)—after Bell.

is of even greater commercial importance, as the horny epidermic plates of the carapace constitute the "tortoise-shell" so largely used for ornamental purposes. The Leathery Turtle is remarkable in having the carapace covered with a leathery skin in place of the horny plates which are found in other species.

(2.) *Trionycidæ*.—The so-called "Soft Tortoises" or "Mud-turtles" are included in this family, and are distinguished by the imperfect development of the carapace, the ribs being expanded and united to one another near their bases only, and its upper surface being covered with a leathery skin. The horny jaws are furnished with fleshy lips; and the feet are five-toed, the toes being webbed, but only three of them bearing nails. All the *Trionycidæ* inhabit fresh water and are carnivorous. A good example is the Soft-shelled Turtle (*Trionyx ferox*) of the Southern United States, which grows to a length of over a foot.

(3.) *Chelydidæ*.—The members of this family are amphibious Chelonians, which have the carapace covered with epidermal shields, and the head and limbs not retractile. Like the preceding, they are carnivorous in habit, and have a hooked and sharp-edged beak. A well-known type is the great Snapping Turtle (*Chelydra serpentina*) of the United States, which grows to a length of four or five feet.

(4.) *Emydidæ*.—The "Terrapins," "Pond-tortoises," and "River-tortoises" included in this family are amphibious in their habits, and live in marshes, ponds, and still streams. The carapace is depressed, and the feet have movable toes united by a web. They live upon both animal and

vegetable food. The *Emydidæ* are widely distributed, many of them being found in North America.

(5.) *Testudinidæ*.—The "Land-tortoises" have a strongly convex carapace, beneath which the head, limbs, and tail can be completely retracted. The limbs are short, with the digits united together and furnished with hoof-like nails. The *Testudinidæ* are terrestrial in their habits and are vegetable feeders. The type-genus is *Testudo*, the species of which are mostly African and Asiatic, though forms are found in Southern Europe and North America. A familiar species is the *Testudo græca*, which inhabits the countries bordering the Mediterranean, and is often imported into this country. Gigantic Land-tortoises, of several species, are found in the Galapagos Islands. Another gigantic species, which grows to four feet in length, is found in Aldabra Island, to the north-west of Madagascar; and another huge species, now extinct, inhabited the Mascarene Islands.

As regards their *distribution in time*, the earliest unequivocal remains of Chelonians are found in the Jurassic rocks, and belong to the marine Turtles (*Cheloniidæ*). Terrapins (*Emydidæ*) also appear in the Secondary period. In the Tertiary rocks remains of all the leading groups of Chelonians are found, the true Land-tortoises being now represented for the first time. A gigantic Chelonian—*Colossochelys atlas*—which seems to have attained a length of fifteen or eighteen feet, is found in the Tertiary deposits of India.

CHAPTER LVI.

OPHIDIA.

ORDER II. OPHIDIA.—The second order of Reptiles is that of the *Ophidia*, comprising the Snakes and Serpents, and distinguished by the following characters:—

The body is always more or less elongated, cylindrical, and worm-like, and whilst possessing a covering of horny scales, is always unprovided with a bony exoskeleton. The dorsal vertebræ are concave in front (*procœlous*), *with rudimentary transverse processes. There is never any sternum, nor pectoral arch, nor fore-limbs, nor sacrum, and the pelvic arches and hind-limbs are wanting, or are only present in a rudimentary condition. The ribs are numerous, but a sternum is not developed. The two rami of the mandible are connected in front by ligaments and muscles only, and the quadrate is movable, as also is the squamosal bone with which it articulates. Hooked conical teeth are present, but they are never sunk in distinct sockets or alveoli. The ventricle of the heart is incompletely divided; the lungs are*

mostly bilaterally unsymmetrical, one being rudimentary or reduced in size; there is no urinary bladder; and the aperture of the cloaca is transverse.

The *exoskeleton* of the Snakes consists of epidermic scales developed upon corresponding areas of the dermis. In gen-

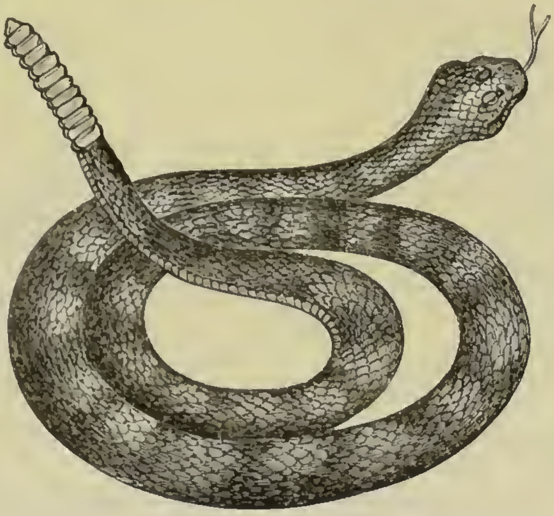

Fig. 374.—The Rattlesnake (*Crotalus durissus*).

eral, the scales are flat and overlap one another, but they are sometimes tubercular and do not overlap. The abdomen is covered with transversely-elongated scales or "scuta," of comparatively large size, and large shields or scutes are often developed in the cephalic region as well (fig. 380). Snakes "moult," or throw off their epidermic investment periodically.

The *endoskeleton* is always ossified, and the vertebral column is very long and is composed of numerous vertebræ (over four hundred in some of the large Pythons), but the number of vertebræ is not constant even in the same species. The centra of the vertebræ are procœlous, and the neural arches of successive vertebræ are joined by accessory articular processes ("zygosphenes" and "zygantra"). The caudal vertebræ have long transverse processes and no ribs. The precaudal vertebræ (except the atlas) carry slender tapering ribs attached to short transverse processes. In the absence of a sternum, the ribs are extremely movable, and are terminated by tapering cartilages, which are attached by muscular connections to the abdominal epidermic shields. By means of this arrangement the Snakes are enabled to glide rapidly along the ground, walking, so to speak, upon the ends of the ribs, the movements of which successively raise and depress the ab-

dominal scuta. This peculiar mode of progression is facilitated by the extreme mobility of the whole vertebral column, conditioned by the cup-and-ball articulation of the bodies of the vertebræ with one another.

The *skull* of the Snakes is well ossified, the cranial bones being distinct. The mandible is complex, and is united to a long and movable quadrate bone (fig. 375, *qu*), which is in

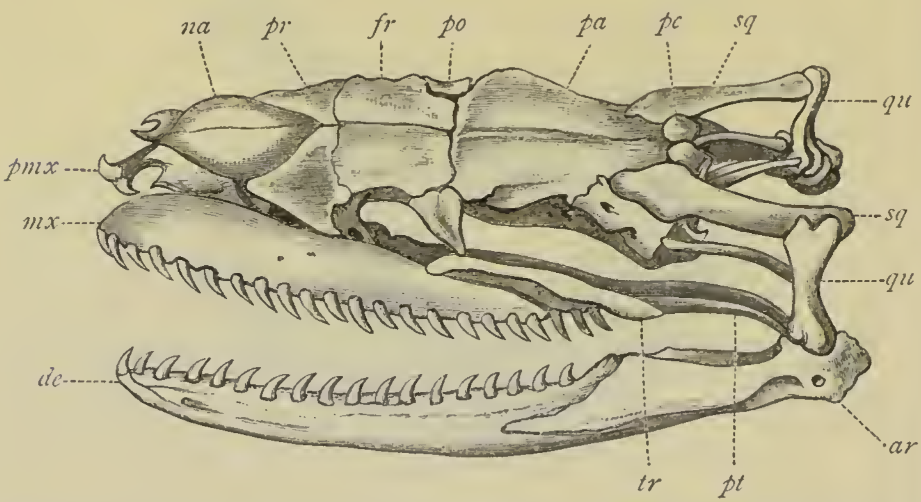

Fig. 375.—Skull of a Constricting Serpent (*Python*). *de* Dentary portion of the mandible; *ar* Articular portion of the mandible; *qu* Quadrate bone; *sq* Squamosal; *pc* Proötic; *pa* Parietal; *po* Postfrontal; *fr* Frontal; *pr* Præfrontal; *na* Nasal; *pmx* Præmaxilla; *mx* Maxilla; *tr* Transverse bone; *pt* Pterygoid.

turn united with a movable squamosal bone (fig. 375, *sq*). The symphysis of the mandible is loose, the two rami being only united by elastic ligaments, and thus moving independently. The maxillæ are sometimes long, with numerous teeth (fig. 375, *mx*), or they may be much shortened, and may carry few teeth, or but a single tooth. The præmaxillæ (*pmx*) are usually toothless, but they are dentigerous in the Pythons. The pterygoid and palatine bones carry more or fewer teeth, as do the dentary pieces of the mandible. All the teeth are conical, recurved, and anchylosed with the bones to which they are attached, being suited for killing or holding the prey, and not for mastication.

Owing to the above peculiarities in the structure of the jaws, and particularly to the backward position of the movable quadrate bones, and the loose mandibular symphysis, Snakes are enabled to open the mouth laterally, as well as vertically, and to swallow comparatively immense morsels entire. Moreover, each mandibular ramus has the power of independent

motion, the prey being drawn into the gullet, by the alternate protrusion and withdrawal of the ramus first on one side and then on the other.

The pectoral limbs and their arches are entirely wanting in all Snakes. The pelvic limbs and their arches are also usually wanting, but are occasionally (*e.g.*, *Python* and *Tortrix*) present in a rudimentary condition, the only outward evidence of their existence being the presence at the sides of the cloacal opening of a pair of short horny claws or spurs ("calcaria").

The tongue in the Snakes (fig. 376, B) is probably an organ more of touch than of taste. It consists of two muscular cylinders, united towards their bases, but free towards their extremities. The bifid organ, thus constituted, can be protruded and

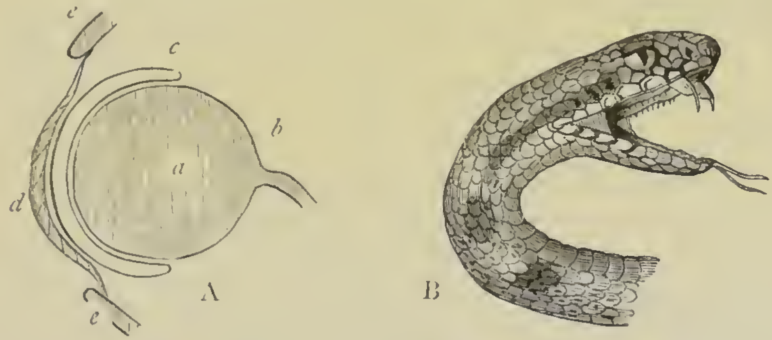

Fig. 376.—A, Diagram of the eye of a Serpent (after Cloquet): *a* Ball of the eye covered by a conjunctival sac, into which the lachrymal secretion is discharged; *b* Optic nerve; *d* Antocular membrane, formed by the epidermis; *e e* Ring of scales surrounding the eye. B, Head of the common Viper (*Pelias berus*), showing the bifid tongue, and the poison-fangs in the upper jaw. (After Bell.)

retracted at will, being in constant vibration when protruded, and being in great part concealed by a sheath when retracted.

As regards the eye of Serpents (fig. 376, A), the chief peculiarity lies in the manner in which it is protected externally. There are no eyelids, and hence the stony unwinking stare of all snakes. In place of eyelids, the eye is surrounded by a circle of scales (*e e*), to the circumference of which is attached a layer of transparent epidermis, which covers the whole eye (*d*), and is termed the antocular membrane. This is covered internally by a thin layer of the conjunctiva, which is reflected forwards from the conjunctiva covering the ball of the eye itself. In this way a cavity or chamber is formed between the two layers of conjunctiva, and the lachrymal secretion, by which the eye is moistened, is received into this. The outer epidermic layer (antocular membrane), covering the ball of the eye in front, is periodically shed with the rest of the

epidermis, the animal being rendered thereby temporarily blind.

The alimentary canal of the Snakes is long, in correspondence with the elongated form of the body, and the transversely-folded intestine opens into the cloaca, the aperture of which is transverse.

The lungs are unsymmetrical, long and tubular. The left lung is in general rudimentary or absent, and the right lung terminates posteriorly in a smooth membranous sac or air-reservoir.

Snakes are for the most part oviparous, laying soft ovate eggs, which are in general hatched by the heat of the sun. The Sea-snakes and Vipers are, however, ovo-viviparous, the eggs being hatched within the oviducts and the young expelled alive.

The Snakes are almost universally distributed, but they are much more abundant in hot regions than in cold, and no forms of the order occur within the Arctic circle. All the large Snakes are inhabitants of tropical regions. The Snakes of cold and temperate regions pass the winter in a state of torpidity. They are all carnivorous, living on animals or on the eggs of birds, and only feeding at prolonged intervals.

As regards their *distribution in time*, the earliest known remains of Ophidians are from the Eocene Tertiary, and indicate the existence of large constricting Serpents (*Palæophis* and *Dinophis*). In some of the later Tertiary deposits the fangs of venomous Snakes have been found. Upon the whole, however, the Ophidians would appear to be a comparatively modern group.

About a thousand species of Snakes are known, of which perhaps a third are poisonous. The order *Ophidia* may be divided into the following sub-orders:—

SUB-ORDER I. SOLENOGLYPHA.—This sub-order includes the Viperine and Crotaline Snakes (Vipers, Rattlesnakes, &c.), characterised by their broad, flattened, triangular heads, and by the nature of their dentition. The maxilla is in these Snakes much shortened, and often hollowed out, and it carries a single large fang, behind which small solid teeth are not developed (fig. 377, *mx*). Not only is the maxilla very short, but it is capable of free movement upon the rounded anterior end of the prefrontal (lachrymal) bone, and the maxilla can be elevated or depressed by the peculiar arrangement of the other bones of the mouth. Thus, articulated with the hinder aspect of the maxilla is a long slender bone (the "transverse bone," or "ectopterygoid" of Owen, fig. 377, *tr*), which in turn is connected behind with the long pterygoid bone. This latter

(fig. 377, *pt*) is connected directly with the front face of the quadrate bone (*qu*). When, therefore, the mouth is opened, the depression of the mandible pushes the quadrate forward, and this in turn pushes the long rod formed by the pterygoid

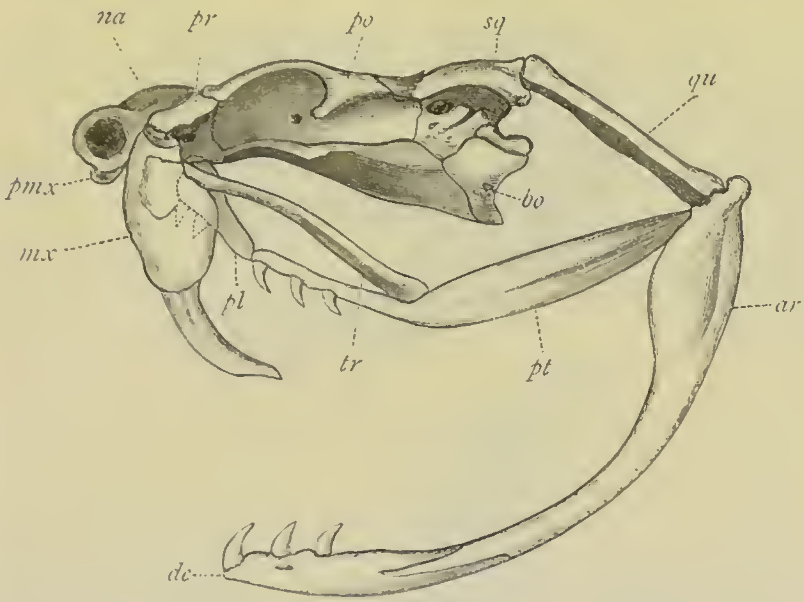

Fig. 377.—Skull of a Rattlesnake (*Crotalus durissus*), viewed from one side: *dc* Dentary portion of the mandible; *ar* Articular portion of the mandible; *qu* Quadrate bone; *sq* Squamosal; *po* Postfrontal; *pr* Prefrontal; *na* Nasal; *pmx* Præmaxilla; *mx* Maxilla, carrying the poison-fang; *pl* Palatine, the front end of the bone being represented by the dotted line as if seen *through* the maxilla; *pt* Pterygoid; *tr* Transverse bone; *bo* Basioccipital. (After Huxley.)

and transverse bones, thus forcing the maxilla to rotate upon the prefrontal, and elevating the fang. On the other hand, when the mouth is closed, the reverse of this takes place, so that the fang comes to lie nearly horizontally along the palate, in which position it is hidden between folds of the mucous membrane of the mouth.

The maxillary fang itself is a long conical tooth, so inrolled upon itself as to give rise to a deep groove along its anterior aspect. In the present group of Snakes, the groove thus formed is converted into an actual canal by the union behind of its bounding laminæ, and the tube thus produced opens at the extremity of the fang by a minute fissure. Connected with the poison-fang is a poison-gland (fig. 378, *a*), which may be regarded as a specially modified salivary gland, and is situated below and behind the eye. This gland secretes the clear viscid fluid which is the "venom" of the poisonous Snakes, and it is covered by one of the muscles of the cheeks. When the animal bites, the contraction of this muscle forces some of

the poison out of the gland into the duct of the fang, whence it penetrates the wound through the opening in the tip of the latter.

Behind the poison-fang in the *Solenoglypha* are situated one

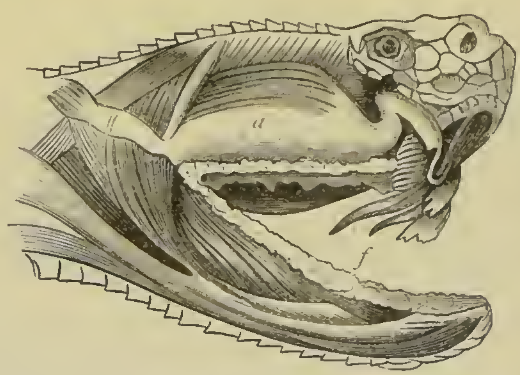

Fig. 378.—The head of the Rattlesnake, dissected to show the poison-gland (*a*) and poison-fangs (*f*). (After Duvernoy.)

or more "reserve-fangs" destined to take the place of the functional fang if the latter should be broken off; but the maxilla carries no other proper teeth except the fang. The palatine and pterygoid bones are, however, provided with small hooked teeth (fig. 377).

The *Solenoglypha* are divided into the two families of the *Viperidæ* and *Crotalidæ*.

(1.) *Viperidæ*.—This family includes the true Vipers, which are destitute of a pit between the eye and nose, and have the head covered with small scales (fig. 380, C). They are viviparous (hence the name "Viper"), and the young Snake is furnished with a temporary præmaxillary tooth, for the purpose of liberating itself from the egg. The Vipers are confined to the Old World, and are characteristic of the Palæarctic and African provinces. The only British species is the common Viper or Adder (*Pelias berus*), which ranges over all Europe and northern Asia. Several Vipers occur in Africa, well-known species being the Horned Viper (*Cerastes ægyptiacus*) of Egypt and the Puff-adder (*Clotho arictans*) of South Africa. Two members of the *Viperidæ* occur in India, of which one—the "Tic-Polonga" or "Daboia" (*Vipera Russellii*)—is widely distributed and very deadly. No member of the family is found in either North or South America.

(2.) *Crotalidæ*.—This family includes the Rattlesnakes (*Crotalus*) and a number of allied forms which are often called "Pit-vipers," as the hollowing out of the maxilla gives rise to a deep pit between the nose and the eye. The head may be covered with small scales only, or scutes may be present as well. The type-genus *Crotalus* includes the true Rattlesnakes, in which the extremity of the tail is furnished with a "rattle," formed of a series of horny epidermic cells of an undulated pyramidal shape, articulated loosely one within the other. Before striking its prey, the Rattlesnake throws itself into a coil and shakes its rattle, as it does also when alarmed. The species of *Crotalus* are exclusively confined to the New World, the common North American species being *C. durissus*, while *Crotalus horridus*

is found in South America. Other well-known types, in which, however, there is no "rattle," are the Copperhead (*Ancistrodon contortrix*) and the Water-mocassin (*Toxicophis piscivorus*) of North America, the Bush-master (*Lachesis mutus*) of Surinam and Guiana, and the various species of *Trimeresurus* in India.

SUB-ORDER 2. PROTEROGLYPHA (*Elapina*).—The Snakes included in this sub-order have the maxilla short, and furnished with poison-fangs, which are grooved in front and are not capable of erection. Behind the grooved fangs are one or more solid conical teeth. The head is covered with large shields. Two families are included in this section.

(1.) *Elapidæ*.—The Snakes of this family are terrestrial in their habits, and have a shield-shaped head not much wider than the body (fig. 380, A).

Fig. 379.—The "Spectacled Snake" (*Naja haje*) of Egypt.

They are found in the tropics in both the Old and New Worlds, and are especially abundant in Australia. The family includes some of the most deadly of all Snakes, one of the best known being the "Cobra" or "Spectacled Snake" (*Naja tripudians*) of India. A closely allied species is the *Naja haje* (fig. 379) of Egypt. In the genus *Naja* the neck is dilatable into a hood, the anterior ribs being elongated and capable of elevation and depression. The genus *Bungarus*, including the deadly "Kerait" (*B. cæruleus*) of India, is nearly allied to *Naja*, but the neck is not dilatable. Another well-known form is the great "Hamadryad" (*Ophiophagus elaps*) of India and the Indian Archipelago, which grows to over ten feet in

length, and is arboreal in its habits. The family is represented in North and South America by the beautifully-marked Coral-snakes and Harlequin Snakes (*Elaps*). Lastly, many genera occur in Australia (*Acanthophis*, *Hoplocephalus*, &c.)

(2.) *Hydrophidæ*.—The "Sea-snakes" have small poison-fangs, with open grooves. The tail is vertically flattened and compressed, being thus adapted for swimming, and the nostrils are placed on the top of the head. The *Hydrophidæ* are essentially aquatic, living in the sea in droves, and feeding on fishes. They are viviparous, and are all very poisonous. They are found in the Pacific, Indian, and Australian Oceans.

SUB-ORDER 3. OPISTHOGLYPHA.—In this sub-order the maxillæ are long, and have several long grooved fangs *behind*, with smaller solid teeth in front. The head is covered with large shields. It is uncertain whether or not they are poisonous. The best-known family of these "suspected" Snakes is that of the Whip-snakes (*Dryophidæ*), which inhabit trees, and are found in the tropics generally, as also are the allied forms included in the *Dipsadidæ* (Nocturnal Tree-snakes).

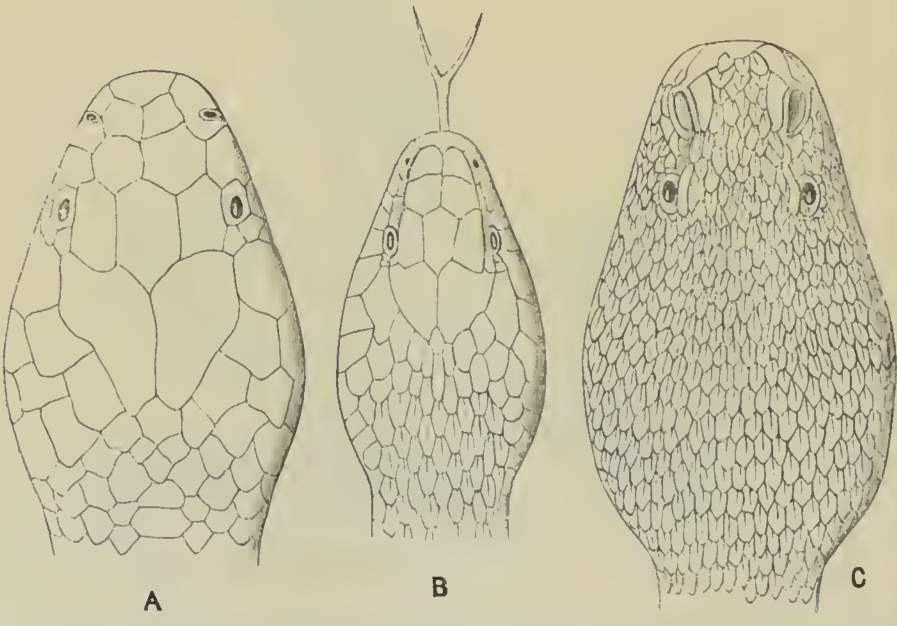

Fig. 380.—Ophidia. A, Head of an Elapine Snake (*Bungarus fasciatus*), viewed from above; B, Head of a Colubrine Snake (*Tropidonotus natrix*); C, Head of a Viperine Snake (*Vipera Russellii*). (A and C are after Sir Joseph Fayrer; B is after Bell.)

SUB-ORDER 4. AGLYPHODONTA.—The members of this sub-order are all non-poisonous, and are characterised by the possession of long maxillæ which carry no grooved fangs, but have numerous solid conical teeth (fig. 375). The head is covered with large shields. The principal families in this section are the *Colubridæ* and the *Perepoda*.

(1.) *Colubridæ.*—This family comprises between two and three hundred species of non-venomous Snakes, which have a universal distribution. The head is in all covered with large shields (fig. 380, B), and is only slightly wider than the neck. Well-known British examples are the Ringed Snake (*Tropidonotus natrix*) and the Smooth Snake (*Coronella lævis*). A common North American species is the Black Snake (*Bascanion constrictor*).

(2.) *Peropoda.*—In this are included the two principal sub-families of the Pythons (*Pythonidæ*) and Boas (*Boidæ*), known usually as Boa-constrictors, Pythons, Anacondas, and Rock-snakes. The Boas and Pythons are of gigantic size, and possess prehensile tails, the hind-limbs being present in a rudimentary condition, in the form of horny spurs placed near the anus. They are called "Constricting Serpents," because after seizing their prey they coil themselves round it in numerous folds, by tightening which they gradually reduce their victim to a shapeless bolus, fit to be swallowed. The true Boas (*Boa*) and the Anacondas (*Eunectes*) are confined to tropical America. The Pythons differ from the Boas in having præmaxillary teeth, and are natives of the Old World, all being confined to the tropics.

SUB-ORDER 5. ANGIOSTOMATA.—This sub-order comprises certain small Snakes with the aberrant characters that the mouth is narrow and not dilatable, the quadrate bone being fixed to the skull, as also is the squamosal (when present). A rudimentary pelvis may be present. Three families—represented by the genera *Tortrix*, *Typhlops*, and *Uropeltis*, and other forms—belong here. They are mostly inhabitants of tropical countries in both the Eastern and Western hemisphere, and commonly burrow in the ground, being not unlike Earth-worms in appearance. The eyes are covered by the skin, and in some cases (*Typhlops*) teeth are wanting in either the upper or the lower jaw.

CHAPTER LVII.

LACERTILIA AND CROCODILIA.

ORDER III. LACERTILIA.—The third order of Reptiles is that of the *Lacertilia*, comprising all those animals which are commonly known as Lizards, together with some serpentiform animals, such as the Blind-worms. The *Lacertilia* are distinguished by the following characters:—

As a general rule, there are *two pairs of well-developed limbs, but there may be only one pair, or all the limbs may be absent. A pectoral arch is always present, whatever the condition of the*

limbs may be. An exoskeleton, in the form of horny scales like those of the Snakes, is almost always present. The vertebræ of the dorsal region are procœlous or concave in front, rarely amphicœlous or concave at both ends. The teeth are not lodged in distinct sockets (some extinct forms constituting an exception to this statement). The heart consists of two auricles and a ventricle, the latter partially divided by an incomplete partition. There is a urinary bladder, and the aperture of the cloaca is transverse.

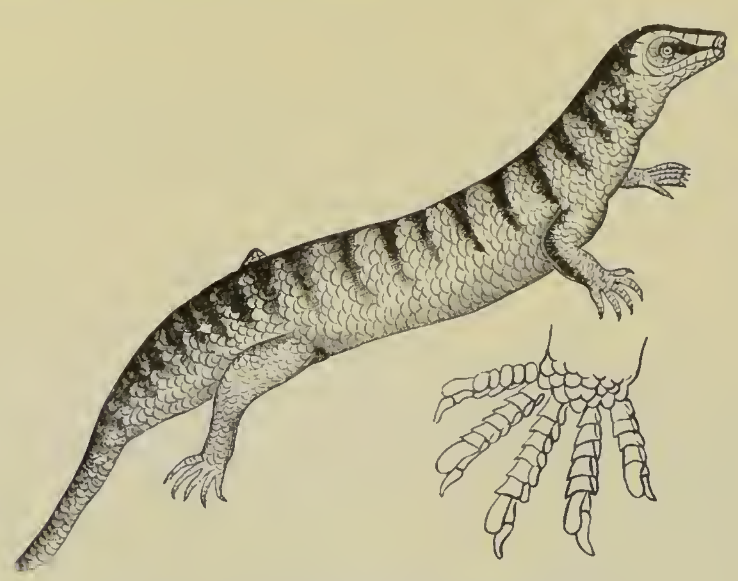

Fig. 381.—The Common Skink (*Scincus officinalis*).

The skin of the Lacertilians is occasionally naked (*Amphisbæna* and *Chamæleo*), but there is generally an *exoskeleton* in the form of horny overlapping scales, sometimes underlaid by bony plates.

The *vertebral column* is usually composed of many vertebræ, and there is generally a long caudal region. The centra of the vertebræ are mostly procœlous, but are amphicœlous in the living Geckos and *Sphenodon*, and in some extinct types. The transverse processes of the vertebræ are short, and those forms which possess hind-limbs have also a sacrum, usually of two vertebræ. The ribs are furnished with undivided heads, and a sternum is developed in all except the *Amphisbænæ*.

In the *skull*, the quadrate bone is in general more or less movable; but the rami of the mandible are firmly united in front, and the Lizards have the gape far more restricted than is the case with the Ophidians. Generally the parietal bone on each side is connected with the pterygoid by a bony rod, known as the "columella."

Teeth are present in all living Lizards, but are only implanted in sockets in some extinct types. In recent forms the teeth are anchylosed with the bones from which they spring, being either fixed by their sides to the inner wall of the alveolar border of the jaw ("pleurodont" dentition), as in the Iguanas (fig. 382), or being attached by their bases to the

Fig. 382.—Inner view of the mandibular ramus of *Iguana*, showing the "pleurodont" dentition.

summit of this border ("acrodont" dentition). In the extinct *Proterosauria* the teeth are in distinct sockets ("thecodont" dentition). The teeth are always simple, but vary much in form, being sometimes sharp and conical (Monitor), sometimes blade-like with serrated edges (Iguana), sometimes with rounded crushing crowns (*Cyclodus*). The teeth may be carried upon the præmaxillæ, maxillæ, mandible, and pterygoid bones, but mostly not upon the palatine bones.

The condition of the *limbs* is extremely variable. Most of the Lacertilians possess both pairs of limbs, and would therefore come under the popular designation of "Lizards." In some (*Chirotes*) there are no hind-limbs; in *Bipes* only the hind-limbs are present, and these are rudimentary; while in others (*Anguis*, *Amphisbœna*, &c.) limbs are wholly wanting, and the animal becomes completely serpentiform in appearance. In all cases, however, whatever the condition of the limbs may be, there exist below the surface the pectoral and pelvic arches, though the development of these may be very imperfect.

The *tongue* of Lizards exhibits three principal modifications in its structure. In one division, including the majority of Lacertilians, the tongue is like that of Serpents in being long, protrusible, and forked (*Fissilinguia* or *Leptoglossa*). In a second group (*Crassilinguia* or *Pachyglossa*), including the Geckos and Iguanas, the tongue is thick, fleshy, and not protrusible. In the so-called *Brevilinguia* the tongue is short, hardly protrusible, and often indented in front. Lastly, in a fourth group (*Vermilinguia*) are placed the Chamæleons, in which the tongue is long and worm-like, with a clubbed extremity, and capable of free protrusion. Salivary glands are wanting in the Lizards, as are poison-glands. The only excep-

tion to this statement is afforded by the *Heloderma suspectum* of Arizona and Mexico, which is capable of inflicting a poisonous bite by means of poison-glands which are situated within the angle of the lower jaw, and are connected with grooved deciduous teeth.

Lastly, the Lizards differ from the Snakes in generally possessing movable eyelids. In the Chamæleons, however, the eyelids become united and are pierced by a central aperture, while in *Amphisbæna* and *Gecko* eyelids are wanting.

About a thousand species of living Lacertilians are known, with a very wide distribution, but being most abundant in warm regions. The majority of Lizards are carnivorous, living upon insects and other small Invertebrates, but some forms are largely or exclusively vegetable-feeders.

As regards their *distribution in time*, the earliest known remains of Lacertilians occur in the Permian rocks, where the aberrant genus *Proterosaurus* is found. In the Trias various Lacertilian types appear (*Telerpeton*, *Hyperodapedon*, &c.). In the succeeding period of the Jurassic occur the remains of small Lizards (*Nuthetes*, *Saurillus*, &c.), which seem to differ little from the typical *Lacertidæ*. Peculiar to the Cretaceous series is the remarkable extinct group of the "Mosasauroids," which will be briefly spoken of hereafter. Lastly, the Tertiary rocks have yielded the remains of numerous Lizards, but these present no features demanding special notice here.

The *Lacertilia* may be briefly considered under the following sub-orders :—

SUB-ORDER I. BREVILINGUIA.—The Lizards included in this section have a short fleshy tongue, which is generally indented at its free end, but is only slightly or not at all protrusible. The three families of the *Amphisbænidæ*, *Chalcididæ*, and *Scincidæ* are placed here.

In the *Amphisbænidæ* the body is serpentiform, and there are either no limbs at all, or short fore-limbs are present (*Chirotes*). There are no scales, but the skin is marked by close-set, transverse and longitudinal furrows, which give it a tesselated appearance. The eyes are minute, and are covered by the skin. The body in *Amphisbæna* is worm-like, with a short tail, and having the vent placed very far back. The species of this genus inhabit the countries round the Mediterranean and South America. *Chirotes* is Mexican.

In the family of the *Chalcididæ* (or *Zonuridæ*), the body is generally more or less snake-like, but the condition of the limbs varies. The scales are mostly rectangular, arranged in transverse bands, and not overlapping. Often there is a longitudinal fold of skin on each side of the body. Some genera (*Chalcides*, *Zonurus*, &c.) have both pairs of limbs. In the Scheltopusiks (*Pseudopus*) of eastern Europe and Asia, rudimentary hind-limbs are present, but there are no fore-limbs. Lastly, in the Glass-

snakes (*Ophisaurus*), of the Southern United States, limbs are altogether wanting.

More important than any of the preceding is the large and widely distributed family of the *Scincidæ*, comprising a number of small Lacertilians, some of which are completely snake-like, whilst others possess a single pair of limbs, and others again have the normal two pairs of limbs in a well-developed condition. All possess movable eyelids, and in all the conformation of the lower jaw is Lacertilian, and not Ophidian. All the Scincoidean Lizards have the body covered by similar scales overlapping one another like the scales of fishes, whilst the head is protected by larger symmetrical plates. The tongue is free, fleshy, and slightly notched.

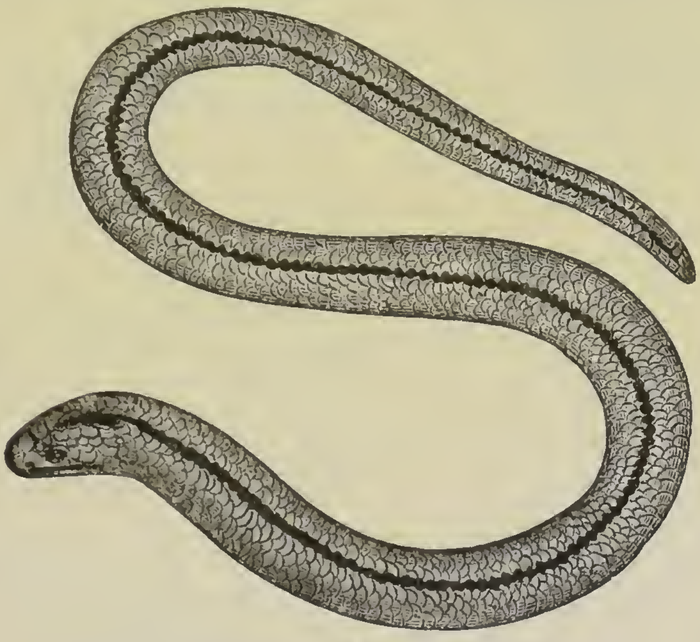

Fig. 383.—The Blind-worm (*Anguis fragilis*)—after Bell.

Of the snake-like forms of this group, none is more familiarly known than the Blind-worm or Slow-worm (*Anguis fragilis*, fig. 383), which is found over almost the whole of Europe, in western Asia, and northern Africa, and which is one of the most abundant of the British Reptiles. The Blind-worm possesses no external appearance of limbs, though the scapular and pelvic arches are present in a rudimentary condition. Its appearance is completely serpentiform, and it is vulgarly regarded as a dangerous and venomous animal, but quite erroneously, as it is even unable to pierce the human skin. It is a perfectly harmless animal, living upon worms, insects, and snails, and hibernating during the winter. It derives its specific name of *fragilis* from the fact that when alarmed it stiffens its muscles to such an extent that the tail can be readily broken off, as if it were brittle.

Numerous other small Lizards are referable to the *Scincidæ*, but it is only necessary to mention the Skinks themselves (*Scincus*), in which both pairs of limbs are present in a well-developed state. The Skinks are found in almost all the warmer parts of the Old World, and closely-allied forms (such as the West Indian "Galliwasp") are found in the New World. The common Skink (fig. 381) is a native of Arabia and Africa. It attains

a length of eight or nine inches, and was formerly used in various diseases as a remedy.

SUB-ORDER II. FISSILINGUIA. — This section comprises the families of the *Lacertidæ*, *Ameividæ*, and *Varanidæ*, in all of which the tongue is long, slender, forked, and freely protrusible.

In the family of the *Lacertidæ* are included the most typical of the Lizards, all of which have a long tail, with four well-developed limbs, each terminated by free toes of unequal lengths. The head is covered with shields, as is the abdomen, those of the latter region being rhomboidal, and arranged in transverse rows. The *Lacertidæ* are mostly confined to the Palæarctic region, and are not represented in America. British species are the Sand-lizard (*Lacerta agilis*) and the Viviparous Lizard (*Zootoca vivipara*). The Green Lizard (*Lacerta viridis*) of the continent of Europe likewise occurs in Jersey.

Very similar in most respects to the preceding, and representing these in the New World, is the family of the *Ameividæ* or "Teguexins." Forms belonging to this family range from Patagonia to the United States, some of them attaining a length of three or four feet.

Very closely allied to the true Lizards are the *Varanidæ* or Monitors, which are indeed chiefly separated by the comparatively trivial fact that the abdomen and head are covered with small non-imbricating scales, and not with large "scuta." The dentition is pleurodont. The tail has a double row of carinated scales, and is cylindrical in the terrestrial forms, and compressed in those whose habits are aquatic. The Monitors are exclusively found in the Old World (Asia, Africa, and Australia), and are the largest of all the recent *Lacertilia;* the *Varanus Niloticus* of Egypt attaining a length of six feet, and the *Hydrosaurus salvator* of the East Indian Archipelago attaining to as much as eight feet.

SUB-ORDER III. PROTEROSAURIA. — This sub-order includes only the extinct genus *Proterosaurus*, which is the oldest type of the Lacertilians at present known, its remains occurring in rocks of Permian age. The special peculiarity of this genus, by which it is distinguished from all existing types, is that the teeth are implanted in distinct sockets. The vertebræ are slightly cupped at both ends, and the neural spines are bifid. The species of *Proterosaurus* attained a length of four feet or more.

SUB-ORDER IV. MOSASAURIA.—The singular reptiles which are included in this section are all extinct, and are confined to the Cretaceous period, some forms attaining a gigantic size. The teeth in this group are conical and curved, and are anchylosed with the jaw, instead of being implanted in distinct sockets. Both the fore and hind limbs are present, and have the form of swimming-paddles (fig. 384), being much shortened, and having the digits distinct, though doubtless enclosed in the integument. In some forms the skin seems to have been provided with bony scutes. The type-genus is *Mosasaurus*.

SUB-ORDER V. CRASSILINGUIA.—This sub-order comprises the three families of the Geckos (*Geckotidæ*), the Iguanas (*Iguanidæ*), and the *Agamidæ*, characterised by their thick, fleshy, non-protrusible tongue, the point of which is rounded, or but slightly indented.

The *Geckotidæ* (*Ascalabotæ*) form a large family of Lizards, comprising a great number of species, occurring in almost all parts of the world between and near the tropics. The tongue is wide, flat, scarcely notched at its free extremity, and hardly at all protrusible. The eyes are large, without proper eyelids, the pupil mostly vertical and linear, but sometimes circular. The vertebræ are amphicœlous. The teeth are numerous, small, compressed, and implanted on the inner edge of the jaw. The nails (when present) are mostly hooked and retractile, and the toes are furnished below with imbricated plates or with adhesive discs (fig. 385). The animal is generally capable of running on the smoothest surfaces, or of suspending itself back downwards. They feed on insects, and are found in abundance in the warmer parts of both the Old and New Worlds.

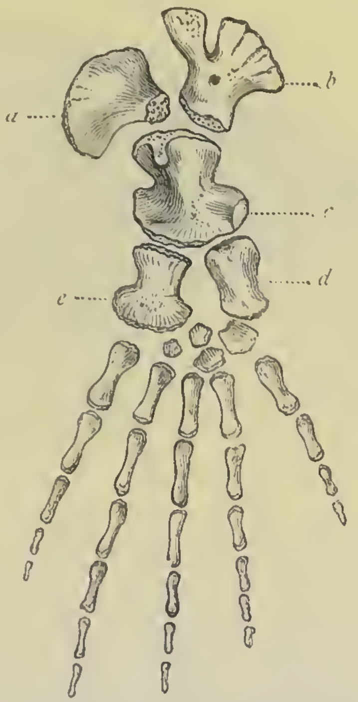

Fig. 384.—Right anterior paddle of *Lestosaurus simus*, one-twelfth of the natural size. (After Marsh.) *a* Scapula; *b* Coracoid; *c* Humerus; *d* Radius; *e* Ulna.

The *Iguanidæ* constitute another large family of Lizards, belonging (if the *Agamidæ* be excluded) almost entirely to the New World. The tongue is thick, fleshy, notched at its extremity only, and not protrusible. The dentition is of the "pleurodont" type. Mostly there is a dorsal crest, and a goitre or throat-pouch. The body is covered with imbricated scales. They are often divided into "Ground-iguanas," in which the body is flat and depressed, and "Tree-iguanas," in which the body is compressed. The members of the genus *Iguana* itself are confined to South America and the West Indies, and are distinguished by having the throat furnished with a pendulous dewlap or fold of skin, the edge of which is toothed. The back and tail, too, are furnished with an erect crest of pointed scales. The common Iguana (*I. tuberculata*) attains a length of from four to five feet, and though not of a very inviting appearance, is highly esteemed as food. The Basilisks (*Basiliscus*) have the top of the head furnished with a membranous sac, which can be distended with air at will.

The family of the *Agamidæ* is closely allied to that of the *Iguanidæ* proper, and represents it in the Old World. The body is covered with imbricated, generally rhombic, scales; the tongue is thick and non-protrusible; the eyes have eyelids; and the teeth are implanted on the edge of the bones of the jaws ("acrodont" dentition).

The Lizards of this group are distributed over nearly the whole of the Old World (principally Asia, Africa, and Australia), and are either arboreal

or terrestrial in habit. Good examples are the *Stellio vulgaris* of the Levant, the *Agama muricata* of Australia, and the hideous *Moloch horridus* of the same country. Here also belongs the curious little Frill Lizard (*Chlamydosaurus*) of Australia, which has the neck furnished on each side

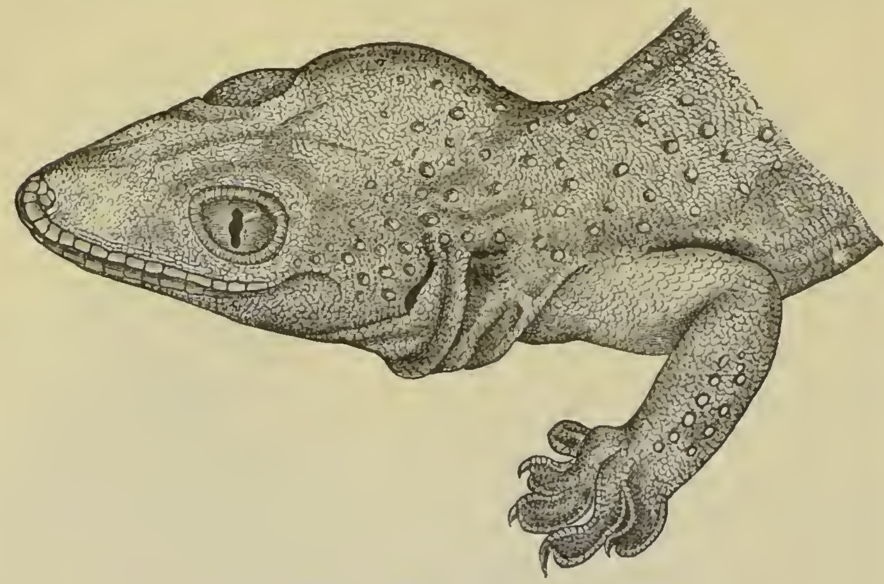

Fig. 385.—Head of *Gecko stentor*. (After Günther.)

with a membranous plaited frill, which can be erected at will. More remarkable than the above are the little Flying Dragons (*Draco*) of the East Indies and Indian Archipelago. In these singular little Lizards there is a broad membranous expansion on each side, formed by a fold of the integument, supported upon the five or six posterior or false ribs, which run straight out from the spinal column (fig. 386). By means of these lateral expan-

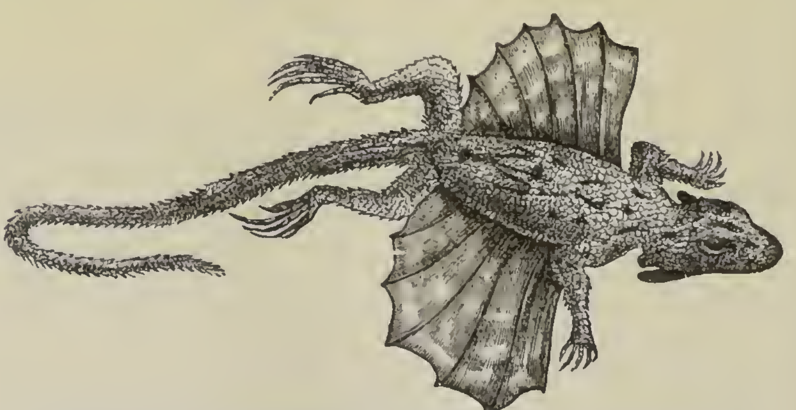

Fig. 386.—The "Flying Dragon" (*Draco volitans*), viewed from above, of the natural size.

sions of the skin, the *Draco* can take long flying leaps from tree to tree, and can pursue the insects on which it feeds; but the lateral membranes simply act as parachutes, and there is no power of true flight, properly so called.

SUB-ORDER VI. VERMILINGUIA.—This sub-order comprises the single family of the *Chamæleontidæ*, with the single genus *Chamæleo*, and is characterised by the possession of a long vermiform tongue, which is club-shaped in front, and can be protruded to a great length. The eye is covered (fig. 387) by a single circular lid, perforated centrally by a small pupil.

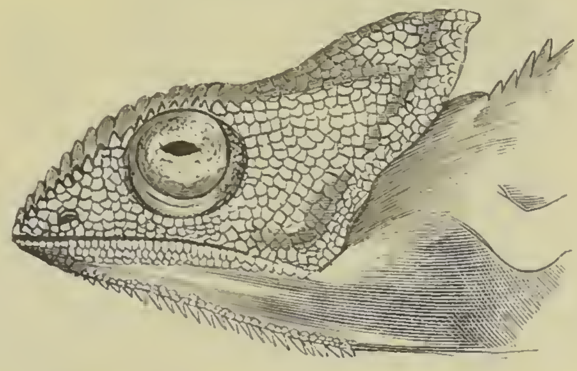

Fig. 387.—Head of a Chamæleon (*C. Petersii*). (After Gray.)

The tail in the Chamæleons is round and prehensile, the body compressed, and the skin like shagreen. The toes are adapted for an arboreal life and scansorial habits, being so arranged as to form two equal and opposable sets. Mobile pigment-cells ("chromatophores") are present in the integument, and the Chamæleons have thus a remarkable power of changing their tints, either at will or under the influence of changes of emotion or of health. The species of *Chamæleo* are exclusively confined to the Old World, and are mostly African. The common Chamæleon (*C. vulgaris*) lives among trees, and is very slow in its movements; but it catches its food, consisting of insects, by darting out its long and glutinous tongue—an operation which it effects with extraordinary rapidity.

SUB-ORDER VII. RHYNCHOCEPHALIA.—This sub-order includes only the single genus *Sphenodon* (*Hatteria*), and is characterised by the fact that the quadrate bone is immovably united with the skull, the vertebræ are amphicœlous, and some of the ribs bear "uncinate processes" similar to those of Birds. Unlike all other Lizards, *Sphenodon* is devoid of copulatory organs. The only known species of the genus is the singular "Tuatara" (*S. punctatus*) of New Zealand, the dentition of which is exceedingly remarkable. The teeth are completely amalgamated by anchylosis with the jaws, and are developed in the mandible, præmaxillæ, and maxillæ, and in a longitudinal series upon the palatine bones. The præmaxillary teeth are two in number, and are of large size and scalpriform in shape. The serrated edge of the mandible is received in the groove between the palatine teeth and the cutting edges of the maxillæ, the alveolar borders of which are hard and as

highly polished as the teeth themselves, the function of which they discharge when the latter are ground down in advanced age. In certain of its characters the genus *Sphenodon*, as

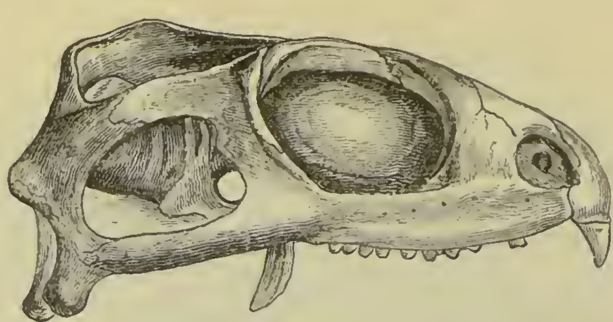

Fig. 388.—Side view of the skull of *Sphenodon* (*Hatteria*) *punctatus*, the lower jaw being removed. (After Günther.)

pointed out by Huxley, shows relationships to the Triassic genera *Hyperodapedon* and *Rhynchosaurus*, and there are grounds for believing that the *Rhynchocephalia* should be placed in the neighbourhood of the extinct order of the Anomodont Reptiles.

CROCODILIA.

ORDER IV. CROCODILIA.—This order includes the living Crocodiles, Alligators, and Gavials, and is distinguished by the following peculiarities: *The exoskeleton consists of horny epidermic scales, conjoined on the dorsal and sometimes also on the ventral surface, with bony dermal scutes. The vertebræ (in living forms) are procœlous, with large transverse processes. The bones of the skull and face are firmly united together, the quadrate is immovably connected with the skull, and the two rami of the mandible are joined in front by suture. There is a single row of teeth in the jaws, implanted in distinct sockets. Both pairs of limbs and their arches are present, the pectoral arch is without a clavicle, and a sternum is present. The septum between the ventricles is complete, but the right and left aortæ are connected just above their origin by the "foramen Panizzæ." There is no urinary bladder, and the aperture of the cloaca is longitudinal.*

The *exoskeleton* of the *Crocodilia* consists of horny epidermic scales, beneath which, in certain regions, bony dermal scutes are developed. In some cases the dermal exoskeleton is only developed dorsally, but in Caiman it is composed of transverse rows of quadrate bony plates, disposed so as to form a dorsal and ventral shield, which are separated by soft skin in the region of the trunk, but become confluent in the tail. All the

scutes of one row are united by suture, and successive rows movably overlap one another. On the back of the neck the scutes are often disposed in groups of different form and number in different species.

The *endoskeleton* is well ossified, and the centra of the vertebræ in all living forms are procœlous. Some of the extinct Crocodiles, however, possessed amphicœlous vertebræ, and in others the vertebræ were opisthocœlous. The neural arches are united to the centra by suture, and there is a sacrum of

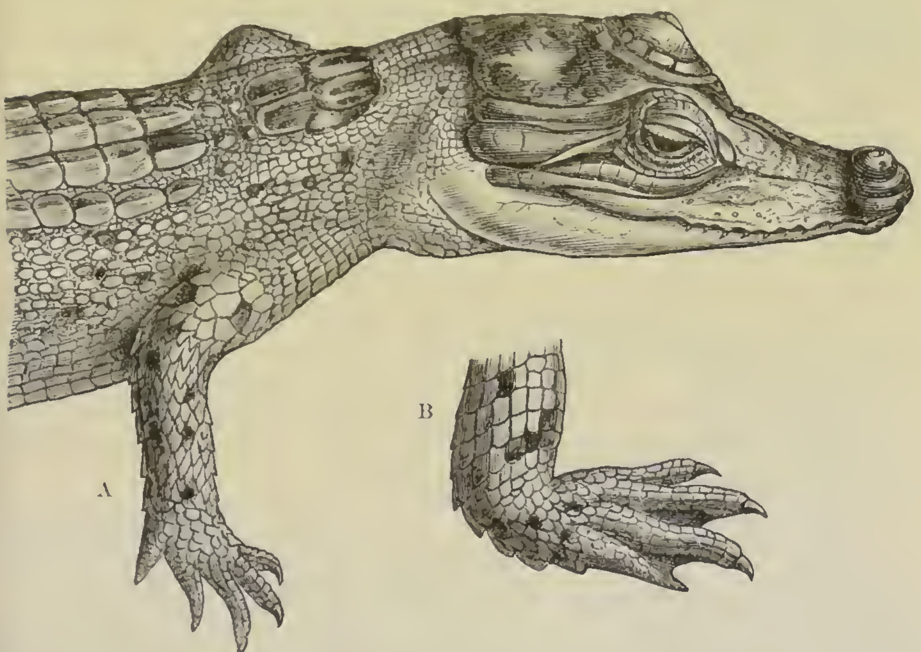

Fig. 389.—A, Head and anterior portion of the body of *Crocodilus pondicerianus*; B, Hind-foot of the same. (After Günther.)

two vertebræ. The cervical vertebræ carry small ribs (hence the difficulty experienced by the Crocodiles in turning quickly), and the vertebral ends of the anterior trunk-ribs are bifurcate. The ribs unite by intermediate bony pieces ("sternal ribs") with a rhomboidal and cartilaginous sternum, which sends backwards a pair of "xiphoid" processes. False abdominal ribs, produced by the ossification of the tendinous intersections of the *recti* muscles, are also present.

The general form of the *skull* is like that of the Lizards, the bones being firmly joined to one another by sutures, and having their surface pitted. The quadrate bone is fixed immovably to the skull. The posterior nares open far back into the throat, thus permitting the animal to breathe while the mouth

may be filled with water, and being correlated with the habit of the Crocodiles of killing their prey by drowning. Teeth are present in a single row in the præmaxillæ, maxillæ, and mandible, but are not developed on the palatine or pterygoid bones. The teeth are conical, and are sunk in sockets, being hollowed out at their bases for the germs of the new teeth, by which they are successively pushed out and replaced during the life of the animal.

Both pairs of *limbs* are present—the anterior ones being pentadactylous, and the posterior tetradactylous. The digits of the hind-feet are more or less completely webbed. The pectoral arch consists of a scapula and coracoid, and though there are no clavicles, a median "interclavicle" is present.

The tongue is thick and fleshy, and immovably attached to the floor of the mouth (hence the belief of the ancients that the Crocodile had no tongue). Salivary glands are wanting, but there open into the mouth two glands which produce a musky secretion. Glands secreting a similar musky substance are also situated close to the termination of the intestine. A muscular diaphragm separates the thorax and abdomen, and the peritoneal cavity communicates with the exterior by "peritoneal canals."

The eye has two eyelids and a "membrana nictitans," or third eyelid, and the external nostrils and openings of the ears are closed by valvular folds of the skin.

The heart differs from that of other Reptiles in the fact that it is completely four-chambered, the septum between the ventricles being complete. The right and left sides of the heart are, however, placed in communication by means of an aperture ("foramen Panizzæ"), connecting together the right (arterial) and the left (venous) aorta just above their point of origin from the left and right ventricles respectively.

The Crocodilians are inhabitants of fresh waters in tropical and subtropical regions, and are found in both the Old and New Worlds. Though essentially aquatic in their habits, they also not uncommonly come to land. They live upon fishes, or upon terrestrial animals which they kill by drowning.

As regards their *distribution in time*, the most ancient types of Crocodilians belong to the sub-order *Amphicœlia*, in which the vertebral bodies were biconcave. These begin in the Trias and range to the Chalk, being thus exclusively Mesozoic. They were marine in their habits, and well-known genera are *Teleosaurus*, *Steneosaurus*, *Stagonolepis*, and *Belodon*. Opisthocœlian vertebræ which have been referred to Crocodiles, for which the special sub-order *Opisthocœlia* has been formed, also occur in

the Mesozoic rocks; but it is questionable if these are really Crocodilian. Lastly, true procœlian Crocodiles occur for the first time in the Greensand (Cretaceous series) of North America. In Europe, however, the earliest remains of procœlian Crocodiles are from the Lower Tertiary rocks (Eocene). It is a curious fact that in the Eocene rocks of the south-west of England, there occur fossil remains of all the three living types of the *Crocodilia*—namely, the Gavials, true Crocodiles, and Alligators; though at the present day these forms are all geographically restricted in their range, and are very partially associated together.

The existing *Crocodilia* may be divided into the following three groups:—

(1.) *Crocodilidæ*.—This family includes the true Crocodiles (*Crocodilus*), distinguished by the fact that the fourth tooth in the mandible ("canine") is longer than the others, and is received into a notch in the alveolar border of the upper jaw, so that it is visible externally when the mouth is closed (fig. 390). The nasal bones take part in the formation of the anterior

Fig. 390.—Skull of Crocodile.

nares, and the hind-feet have the toes completely united by the skin. The true Crocodiles are very widely distributed—species of *Crocodilus* being found in Africa, India, Malacca, and the Indian Archipelago, and ranging to North Australia; while other forms inhabit Cuba, Central America, and the northern part of South America. The best-known species are the *Crocodilus vulgaris* of Africa and the *C. bifurcatus* of Madagascar and the Oriental province.

(2.) *Alligatoridæ*.—This family includes the Alligators, in which the fourth mandibular tooth ("canine") is received into a pit in the palatal surface of the upper jaw, so that it is concealed when the mouth is shut. The nasal bones take part in the formation of the anterior nostrils, and the toes of the hind-feet are incompletely webbed. There is often an abdominal

series of dermal scutes. The Alligators are confined to the warmer parts of North and South America, and the best-known species are the *Alligator lucius* of the Southern United States, the Caiman (*A. palpebrosus*) of Surinam and Guiana, and the "Jacaré" or Spectacled Alligator (*A. sclerops*) of Brazil.

(3.) *Gavialidæ.*—This group includes the so-called "Gavials" or "Gharrials," characterised by their very elongated snouts, and by the fact that the nasal bones are excluded from the anterior nares. The first and fourth mandibular teeth are received into notches in the upper jaw. The best-known member of this family is the "Gavial" (*Gavialis Gangeticus*) of the Ganges and other large Indian rivers. Two species, belonging to the allied genus *Tomistoma*, are found in Borneo and North Australia respectively.

CHAPTER LVIII.

EXTINCT ORDERS OF REPTILES.

THERE remain a number of groups of extinct Reptiles which differ so widely from existing types that they may best be considered separately from the latter. All the groups in question are essentially, if not exclusively, Mesozoic in their range, and they may be very briefly considered here under the following heads:—

ORDER V. ICHTHYOPTERYGIA, Owen (= *Ichthyosauria*, Huxley).—The gigantic Saurians forming this order are distinguished by the following characters:—

The body was fish-like, without any distinct neck, and probably covered with a smooth or wrinkled skin, no horny or bony exoskeleton having been ever discovered. The vertebræ were numerous, deeply biconcave or amphicœlous, and having the neural arches united to the centra by a distinct suture. The anterior trunk-ribs possess bifurcate heads. There is no sacrum, and no sternal ribs or sternum, but clavicles were present as well as an interclavicle (episternum); and false ribs were developed in the walls of the abdomen. The skull had enormous orbits separated by a septum, and an elongated snout. The eyeball was protected by a ring of bony plates in the sclerotic. The teeth were not lodged in distinct sockets, but in a common alveolar groove. The fore and hind limbs were converted into swimming-paddles (fig. 392), the ordinary number of digits (five) remaining recognisable, but the phalanges being greatly increased in number, and marginal ossicles being added as well. A vertical caudal fin was in all probability present.

The order *Ichthyopterygia* includes only, or principally, the gigantic and fish-like *Ichthyosauri* (fig. 391), all exclusively Mesozoic, and abounding in the Lias, Oolites, and Chalk, but especially characteristic of the Lias.

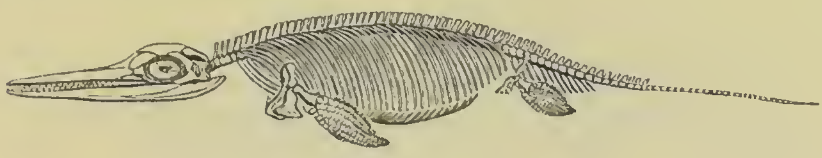

Fig. 391.—*Ichthyosaurus communis.*

The genus *Sauranodon*, described by Marsh from the Jurassic rocks of North America, may also be provisionally placed here. It agrees with *Ichthyosaurus* in the general structure of the skeleton, but teeth are absent. The *Ichthyosauri* were inhabitants of the sea, and were exclusively carnivorous in their

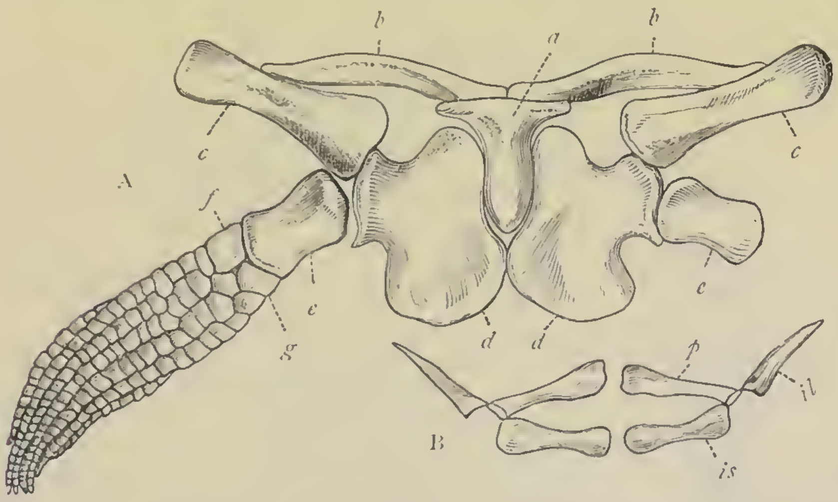

Fig. 392.—A, Pectoral arch and fore-limbs of *Ichthyosaurus: a* Interclavicle; *b b* Clavicles; *c c* Scapulæ; *d d* Coracoids; *e* Humerus; *f* Ulna; *g* Radius. (Somewhat altered from Huxley.) B, Pelvis of *Ichthyosaurus: p* Pubis; *il* Ilium; *is* Ischium. (After Huxley.)

habits. They have been commonly included with the next order (*Sauropterygia*) in a common group, under the name of *Enaliosauria* or Sea-lizards.

ORDER VI. SAUROPTERYGIA, Owen (= *Plesiosauria*, Huxley).—This order of extinct Reptiles, of which the well-known *Plesiosaurus* may be taken as the type, is characterised by the following peculiarities:—

The body, as far as is known, was naked, and not furnished with any horny or bony exoskeleton. The bodies of the ver-

tebræ were either flat or only slightly cupped at each end, and the neural arches were anchylosed with the centra, and did not remain distinct during life. The transverse processes of the vertebræ were long, and the anterior trunk-ribs had simple, not bifurcate heads. No sternum or sternal ribs are known to have existed, but there were false abdominal ribs. The neck (fig. 393) in most was greatly elongated, and composed of

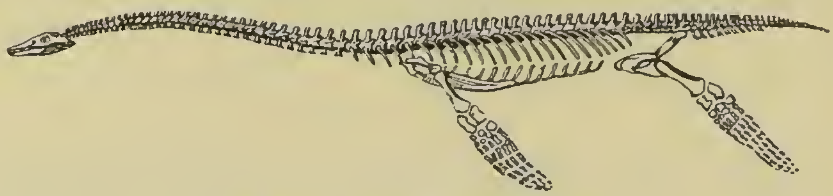

Fig. 393.—*Plesiosaurus dolichodeirus.*

numerous vertebræ. The sacrum was composed of two vertebræ. The orbits were of large size, and there was a long snout, as in the Ichthyosauri, but there was no circle of bony plates in the sclerotic. The limbs agree with those of the Ichthyosauri in being in the form of swimming-paddles (fig. 394), but differ in not possessing any supernumerary marginal ossicles. A pectoral arch, formed of two clavicles and an interclavicle (episternum), appears to have been sometimes, if not always, present. The teeth were simple, and were inserted into distinct sockets, and not lodged in a common groove.

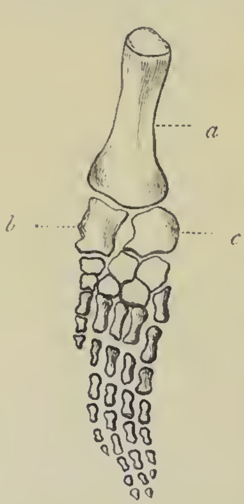

Fig. 394.—Left fore-paddle of *Plesiosaurus*. *a* Humerus; *b* Radius; *c* Ulna.

The most familiar and typical member of the *Sauropterygia* is the *Plesiosaurus* (fig. 393), a gigantic marine reptile, chiefly characteristic of the Lias and Oolites, but ranging to the Chalk, specimens having been found indicating a length in some species of eighteen or twenty feet. Allied to *Plesiosaurus* are the Triassic genera *Simosaurus* and *Nothosaurus*, which are chiefly characteristic of the formation of the Muschelkalk.

ORDER VII. ANOMODONTIA, Owen (= *Dicynodontia*, Huxley).—The leading characters of this order are to be found in the structure of the jaws, which appear to have been sheathed in horn so as to constitute a kind of beak, very like that of the Chelonians. In the genus *Oudenodon* (fig. 395), both jaws seem to have been altogether destitute of teeth; but in *Dicy-*

nodon (fig. 395, A) there were two long tusks, growing from persistent pulps, placed one on each side in the upper jaw. The pectoral and pelvic arches were very strong, and the limbs were well developed and fitted for walking, and not for swim-

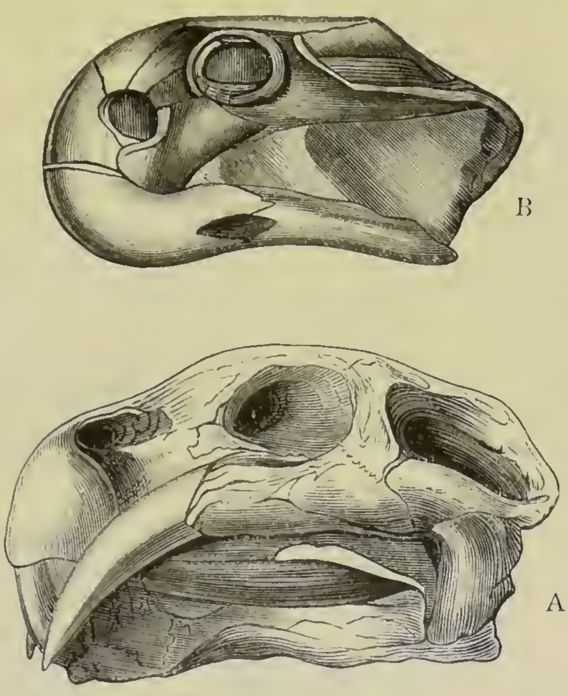

Fig. 395.—A, Skull of *Dicynodon lacerticeps*, showing the maxillary tusk. B, Skull of *Oudenodon Bainii*. From the Trias of South Africa. (After Owen.)

ming. The dorsal vertebræ were amphicœlous, and the anterior trunk-ribs had double heads.

The genera *Oudenodon* and *Dicynodon* comprise large Reptiles, the remains of which have been found in strata of Triassic age in South Africa and India. The genus *Rhynchosaurus*, of the Trias of Europe, is also placed here by Owen, but it is regarded as Lacertilian in its affinities by Professor Huxley. There are points of relationship between the Anomodonts and the singular living genus *Sphenodon* (*Hatteria*), and it is possible that the *Rhynchocephalia* should be regarded as a subdivision of the present order. The singular Triassic genus *Placodus*, in which the teeth have the form of broad crushing plates, may represent another division of the *Anomodontia*. Lastly, the following order of the *Theriodontia* may probably be considered as in reality only a sub-order of the Anomodont Reptiles.

ORDER VIII. THERIODONTIA.—This order has been founded

by Professor Owen for the reception of a number of carnivorous Reptiles from deposits of Triassic or Permian age. The Reptiles in question show some singular affinities to the Mammals, especially to the Beasts of Prey. The dentition is of the carnivorous type, the teeth being in three distinct sets—viz., incisors, canines, and molars, and the canines being large and pointed.

In *Cynodraco*, which may be regarded as the type of the group, the canines are not only of immense size, but are com-

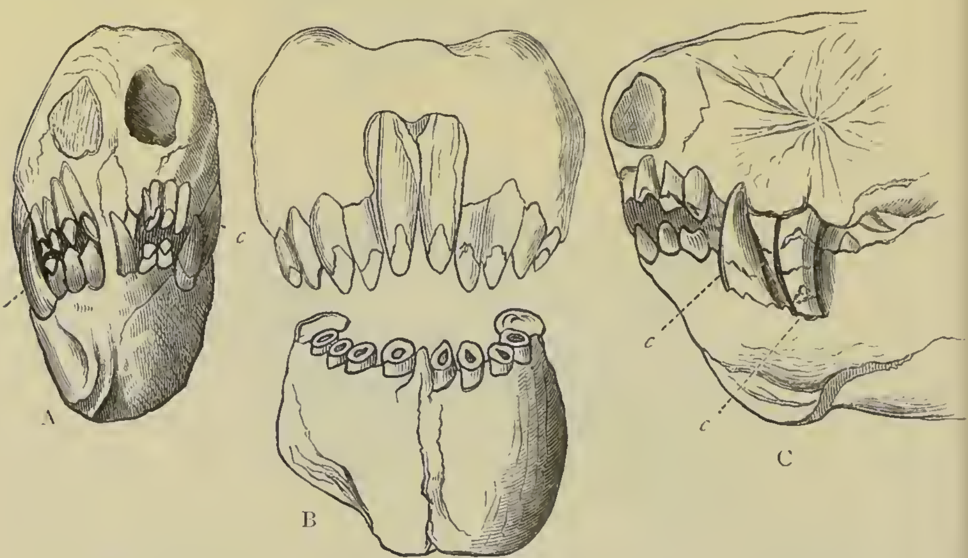

Fig. 396.—A, Front view of the skull of *Lycosaurus*, showing the dentition. B, Front view of the jaws of *Cynodraco serridens*, showing the incisor teeth. C, Side view of the jaws of *Lycosaurus*, showing the incisors and the laniariform canines ; *c* Canines. (After Owen.)

pressed in shape, and have the hinder trenchant border of the tooth minutely serrated, thus resembling the canines of the Sabre-toothed Tiger (*Machairodus*). The humerus is, further, furnished with a "supra-condyloid foramen" (similar to that of the humerus of *Felidæ* and other carnivorous Mammals) for the protection of the median nerve and brachial artery on their way down the arm. Whilst *Cynodraco* is the type of the *Theriodontia*, Prof. Owen is of opinion that a number of other genera (such as *Galesaurus*, *Cynochampsa*, *Lycosaurus*, &c.), principally of Triassic age, are likewise referable to the same order.

ORDER IX. PTEROSAURIA (*Ornithosauria*, Seeley).—This order includes a group of extraordinary flying Reptiles, all belonging to the Mesozoic epoch, and exhibiting in many respects a very extraordinary combination of characters.

The most familiar members of the order are the so-called "Pterodactyles," and the following are the characters of the order :—

No exoskeleton is known to have existed. The dorsal vertebræ are procœlous, and the anterior trunk-ribs are double-headed. There is a broad sternum with a median ridge or keel, and ossified sternal ribs. The jaws were generally armed with teeth, and these were implanted in distinct sockets. In some forms (*Rhamphorhynchus*) there appear to have been no teeth in the anterior portion of the jaws, and these parts seem to have been sheathed in horn, so as to constitute a kind of beak. In the genus *Pteranodon*, from the Cretaceous rocks of North America, comprising gigantic examples of the order, the jaws are completely destitute of teeth, and appear to have been encased in a horny beak.

A ring of bony plates occurs in the sclerotic coat of the eye. The pectoral arch consists of a scapula and distinct coracoid bone, articulating with the sternum as in Birds, but no clavicles have hitherto been discovered. The fore-limb (fig. 397) consists of a humerus, ulna and radius, carpus, and

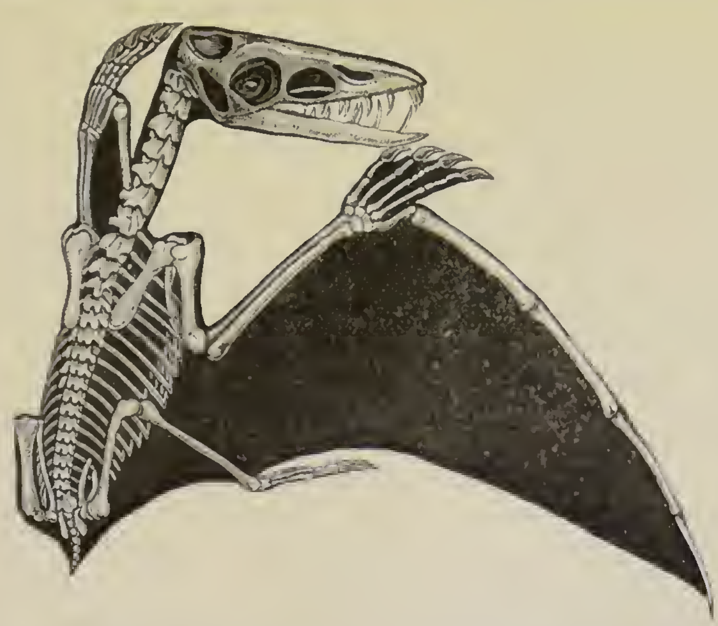

Fig. 397.—*Pterodactylus crassirostris.* From the Lithographic Slates of Solenhofen (Upper Oolite). In accordance with the view originally entertained, the digits of the hand are here erroneously represented as five instead of four in number.

hand of four fingers, of which the inner three are short and unguiculate, whilst the outermost is clawless and is enormously elongated. Between this immensely-lengthened finger, the

side of the body, and the comparatively small hind-limb, there was supported an expanded flying-membrane, or "patagium," which the animal must have been able to employ as a wing, much as the Bats of the present day. Lastly, most of the bones were "pneumatic"—that is to say, were hollow and filled with air.

The *Pterosauria* are exclusively Mesozoic, being found from the Lower Lias to the Chalk inclusive, the Lithographic Slate of Solenhofen (Jurassic) being particularly rich in their remains. Most of them appear to have attained no very great size, but the remains of a species from the Cretaceous rocks have been considered to indicate an animal with more than twenty feet expanse of wing, counting from tip to tip.

In the genus *Pterodactylus* proper, the jaws are provided with teeth to their extremities, all the teeth being long and slender.

In *Dimorphodon*, the anterior teeth are large and pointed, the posterior teeth small and lancet-shaped.

In *Rhamphorhynchus*, the anterior portion of both jaws is edentulous, and may have formed a horny beak, but teeth are present in the hinder portion of the jaws.

In *Pteranodon*, lastly, the jaws are completely edentulous, and were probably ensheathed in horn. This genus, along with some small forms, includes the largest known members of the order.

ORDER X. DINOSAURIA, or DEINOSAURIA.—The last order of extinct Reptiles is that of the *Dinosauria*, comprising a group of very remarkable Reptiles, which are in some respects intermediate in their characters between the Struthious Birds and the typical Reptiles; whilst they have been supposed to have affinities to the Pachydermatous Mammals. Most of the *Dinosauria* were of gigantic size, and the order is defined by the following characters:—

The skin was sometimes naked, sometimes furnished with a well-developed exoskeleton, consisting of bony shields. A few of the anterior vertebræ were opisthocœlous, the remainder having flat or slightly biconcave bodies. The anterior trunk-ribs were double-headed. The teeth were confined to the jaws and mostly implanted in distinct sockets. There were always two pairs of limbs, and these were strong, furnished with claws, and adapted for terrestrial progression. In some cases the fore-limbs were very small in proportion to the size of the hind-limbs. No clavicles have been certainly identified, except in *Iguanodon* and its allies.

The teeth are sometimes implanted in distinct sockets, and they are never anchylosed with the jaws. The ischium and pubes are much elongated; the inner wall of the acetabulum is formed by membrane; the tibia has its proximal end prolonged anteriorly into a strong crest; and the astragalus is bird-like (Huxley).

The most remarkable points in the organisation of the *Dinosauria* are connected with the structure of the pelvis and hind-limb, the characters of which, as pointed out by Huxley, approximate to those of the same parts in the Birds, and especially in the Struthious Birds. This approximation is especially seen in the prolongation of the ilium in front of the acetabulum (fig. 398), the elongation and slenderness of form of the ischium, and the slenderness of the pubes. The astragalus is like that of a bird, and in some cases appears to have become anchylosed with the distal end of the tibia. The metatarsal bones, however, remain distinct, and are not anchylosed with any of the tarsal bones to form a "tarso-metatarsus."

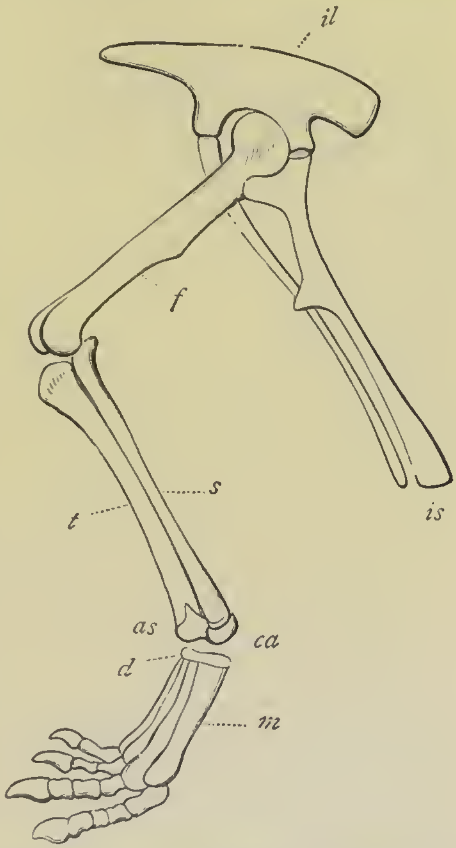

Fig. 398.—Leg of Deinosaur. *il* Ilium; *is* Ischium; *f* Femur; *t* Tibia; *s* Fibula; *as* Astragalus; *ca* Calcaneum; *m* Metatarsus. (After Huxley.)

The most familiar examples of the *Dinosauria* are *Megalosaurus* and *Iguanodon*.

Megalosaurus is a gigantic Oolitic Reptile, which occurs also in the Cretaceous series (Weald Clay). Its length has been estimated at between forty and fifty feet, the femur and tibia each measuring about three feet in length. As the head of the femur is set on nearly at right angles with the shaft, whilst all the long bones contain large medullary cavities, there can be no doubt but that *Megalosaurus* was terrestrial in its habits. That it was carnivorous and destructive in the highest degree is shown by the powerful, pointed, and trenchant teeth.

The *Iguanodon* is mainly, if not exclusively, Cretaceous, being especially

characteristic of the great delta-deposit of the Wealden. The length of the *Iguanodon* has been estimated as being probably from fifty to sixty feet; and from the close resemblance of its teeth to those of the living Iguanas, there is little doubt that it was herbivorous and not carnivorous. The femur of a large *Iguanodon* measures from four to five feet in length, with a circumference of twenty-two inches in its smallest part. From the disproportionately small size of the fore-limbs, and from the occurrence of *pairs* of gigantic three-toed footsteps in the same beds, it has been concluded, with much probability, that *Iguanodon*, in spite of its enormous bulk, must have walked temporarily or permanently upon its hind-legs, thus coming to present a most marked and striking resemblance to the Birds.

LITERATURE.

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DIVISION II.—SAUROPSIDA.

CHAPTER LIX.

CLASS IV.—AVES.

The fourth class of the *Vertebrata* is that of *Aves*, or Birds. The Birds may be shortly defined as being "oviparous Vertebrates with warm blood, a double circulation, and a covering of feathers" (Owen). More minutely, however, the Birds are defined by the possession of the following characters:—

The embryo possesses an amnion and allantois, and branchiæ or gills are never developed at any time of life upon the visceral arches. The skull articulates with the vertebral column by a single occipital condyle. The form of the vertebral centra varies; but they are in no case amphicœlous, except in the remarkable extinct form described under the name of *Ichthyornis*. Each half or ramus of the lower jaw consists of a number of pieces, which are separate from one another in the embryo; and the jaw is united with the skull, not directly, but by the intervention of a quadrate bone (as in the Reptiles). The fore-limb in no existing birds possesses more than three digits, and the metacarpal bones are anchylosed together. In all living birds the fore-limbs are useless as regards prehension, and in most they are organs of flight. The hind-limbs in all birds have the ankle-joint placed in the middle of the tarsus, the proximal portion of the tarsus coalescing with the tibia, and the distal portion of the tarsus being anchylosed with the second, third, and fourth metatarsals to constitute a single bone known as the "tarso-metatarsus." There are never more than four digits in the pes.

The heart consists of four chambers, two auricles, and two ventricles; and not only are the right and left sides of the heart completely separated from one another, but there is no communication between the pulmonary and systemic circula-

tions, as there is in Reptiles. There is only one aortic arch, the right. The blood is hot, having an average temperature of as much as 103° to 104°. The red blood-corpuscles are oval and nucleated.

The respiratory organs are in the form of spongy cellular lungs, which are not freely suspended in pleural sacs; and the bronchi open on their surface into a number of air-sacs, placed in different parts of the body.

The intestine terminates in a "cloaca," into which open the ducts of the urinary and reproductive organs.

All birds are oviparous, none bringing forth their young alive, or being even ovo-viviparous. All birds are, lastly, provided with an epidermic covering, so modified as to constitute what are known as *feathers*.

Professor Huxley's account of the method in which feathers are produced is so remarkably clear, that no apology is necessary for quoting it in its entirety. Feathers "are evolved within sacs from the surface of conical papillæ of the dermis. The external surface of the dermal papilla, whence a feather is to be developed, is provided upon its dorsal surface with a median groove, which becomes shallower towards the apex of the papilla. From this median groove, lateral furrows proceed at an open angle, and passing round upon the under surface of the papilla, become shallower, until, in the middle line, opposite the dorsal median groove, they become obsolete. Minor grooves run at right angles to the lateral furrows. Hence the surface of the papilla has the character of a kind of mould, and if it were repeatedly dipped in such a substance as a solution of gelatine, and withdrawn to cool until its whole surface was covered with an even coat of that substance, it is clear that the gelatinous coat would be thickest at the basal or anterior end of the median groove, at the median ends of the lateral furrows, and at those ends of the minor grooves which open into them; whilst it would be very thin at the apices of the median and lateral grooves, and between the ends of the minor grooves. If, therefore, the hollow cone of gelatine, removed from its mould, were stretched from within, or if its thinnest parts became weak by drying, it would tend to give way along the inferior median line, opposite the rod-like cast of the median groove, and between the ends of the casts of the lateral furrows, as well as between each of the minor grooves, and the hollow cone would expand into a flat feather-like structure, with a median shaft and a 'vane' formed of 'barbs' and 'barbules.' In point of fact, in the development of a feather, such a cast of the dermal papilla is formed, though not in gelatine, but in the horny epidermic layer developed upon the mould, and as this is thrust outwards, it opens out in the manner just described. After a certain period of growth the papilla of the feather ceases to be grooved, and a continuous horny cylinder is formed, which constitutes the 'quill.'"

A typical feather (fig. 399) consists of the following parts:— 1. The "quill" or "calamus" (*a*), which forms the basal portion of the feather, by which it is inserted in the skin on its own dermal papilla. It is the latest-formed portion of the feather, and consists of a hollow horny cylinder. 2. The

"shaft" or "rachis" (*b*), which is simply a continuation of the quill, and which forms the central axis of the feather. The inferior surface of the shaft always exhibits a strong longitudinal groove, and it is composed of a horny external sheath, containing a white spongy substance, very like the pith of a plant. 3. The shaft carries the lateral expansions or "webs" of the feather, collectively constituting the "vane" or "vexillum." Each web is composed of a number of small branches, which form an open angle with the shaft, and which are known as the "barbs" (*c*). The margins of each barb are, in turn, furnished with a series of still smaller branches, which are known as the "barbules." As a general rule, the extremities of the barbules are hooked, so that those springing from the one side of each barb interlock with those springing from the opposite side of the next barb. In this way the barbs are kept in apposition with one another over a greater or less portion of the entire web. More or less of the barbs in the lower portion of the feather are, however, disunited, and not connected by their barbules; and these constitute what is known as the "down." In the Ostriches, Emeus, and allied birds, all the barbs of the feathers are disconnected, giving to the plumage of these birds its peculiarly soft character. At the point where the shaft joins the quill, and on the under side of the former, there is very generally found a small feather, known as the "accessory plume" or "after-shaft" ("hyporachis"). This is usually much the same in structure as the main feather, but considerably smaller. It may, however, be as large as the original

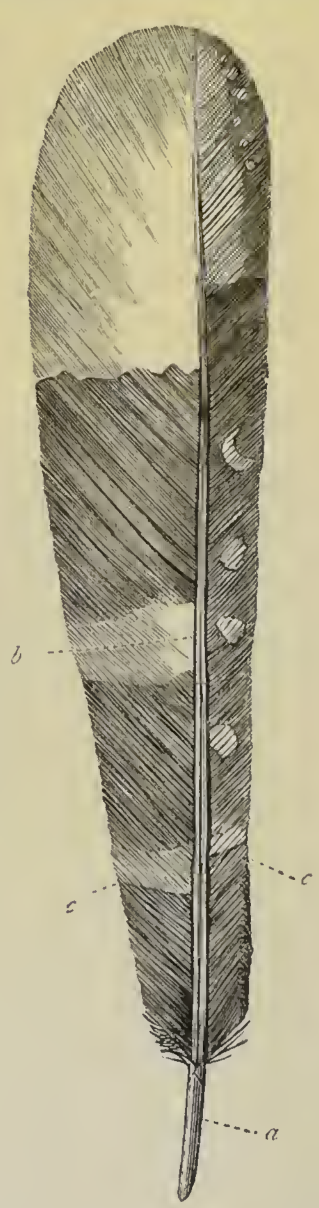

Fig. 399.—Quill-feather (*Stenopsis*). *a* Quill or barrel; *b* Shaft; *cc* Webs, composed of the barbs, and together forming the "vane."

feather, or it may be reduced to nothing more than a tuft of down.

The feathers vary in different parts of the bird, and are generally divided into those which cover the body—"clothing-feathers" or "contour-feathers"—and those which occur in the wings and tail—"quill-feathers." As regards the great quill-feathers of the wings, the longest are those which arise from the bones of the hand, and they are called the "primaries." Those which arise from the distal end of the fore-arm (radius and ulna) are termed the "secondaries," and those which are attached to the proximal end of the fore-arm are the "tertiaries." The feathers which lie over the humerus and scapula are the "scapulars." The rudimentary "thumb" also carries some quills, which form what is known as the "alula," or "bastard-wing." The smaller feathers, which cover the bases of the quill-feathers above and below, are the "wing-coverts"—"greater," "lesser," and "under." The great quill-feathers of the tail ("rectrices") form a kind of fan, of great use in steering the bird in flight; and their bases are covered by a series of feathers which constitute the "tail-coverts." Generally there are ten or twelve "rectrices"; but there may be as many as twenty-four (as in the Pelican), or rarely more; and they do not carry "accessory plumules." In addition to the "clothing-feathers" and the quill-feathers of the wings and tail, the body is protected by a more or less abundantly developed coating of "down-feathers" ("plumulæ"), in which the barbules are not hooked, and the barbs are therefore free. In some cases there is no shaft to the down-feathers, and the barbs are attached in a tuft to the end of the quill. In other cases, the feathers closely approximate to hairs in form, being very long, slender, and flexible. These "filoplumæ" consist of a delicate shaft, either destitute of vanes, or carrying a few barbs at the extremity.

Though apparently completely covered with feathers, these appendages are really almost always confined to certain special tracts ("pterylæ") in the body of a bird, the intervening spaces ("apteria") being, with few exceptions, naked. These feathered and unfeathered regions are definite in form, size, and arrangement in many great groups of birds, and can thus be used as an important aid to classification.

Other exoskeletal structures in Birds, in addition to feathers, are the horny scales and shields which cover the unfeathered portions of the leg and toes, the horny spurs on the wings of some birds, and the horny beak in which the jaws are ensheathed. Specially modified tracts of the skin, highly vascular, and sometimes erectile, constitute the "combs" and "wattles" of many male birds. Lastly, though sudoriparous and sebaceous glands are absent, most Birds possess a special oil-gland placed at the root of the tail, secreting an oily fluid for lubricating the feathers, and opening by a single or double aperture.

The entire *skeleton* of the Birds is singularly compact, and at the same time singularly light. The compactness is due to the presence of an unusual amount of phosphate of lime; and the lightness, to the absence in many of the bones of the ordinary marrow, and its replacement by air.

As regards the *vertebral column*, birds exhibit some very interesting peculiarities. The cervical region of the spine is unusually long and flexible, since the fore-limbs are useless as organs of prehension, and all acts of grasping must be exer-

cised either by the beak or by the hind-feet, or by both acting in conjunction. In all birds alike, the neck is sufficiently long and flexible to allow of the application of the beak to an oil-gland placed at the base of the tail, this act being necessary for the due performance of the operation of "preening"—that is, of lubricating and cleaning the plumage. The cervical vertebræ vary in number from eight to twenty-three. The front faces of their centra are cylindroidal (spheroidal in Penguins), *convex from above downwards, and concave from side to side*, the posterior faces being *saddle-shaped*, concave from above downwards and convex from side to side. Hence in *vertical* section, the vertebræ appear to be *opisthocœlous*, and in *horizontal* section *procœlous*. This structure of the cervical vertebræ is highly characteristic of Birds. The dorsal vertebræ vary from six to ten in number, and of these the anterior four or five are generally anchylosed with one another, so as to give a base of resistance to the wings. In the Ratite Birds, however (such as the Ostrich and Emeu), and in some others (such as the Penguin), in which the power of flight is wanting, the dorsal vertebræ are all more or less freely movable upon one another. There are no free lumbar vertebræ, but all the vertebræ between the last dorsal and the first caudal (varying from eleven to twenty) are anchylosed together to form a bone which is ordinarily known as the "sacrum." To this, in turn, the iliac bones are anchylosed along their whole length, giving perfect immobility to this region of the spine and to the pelvis. The anterior vertebræ of the so-called "sacrum" are in reality lumbar vertebræ; the two or three vertebræ behind these are properly sacral, and the anchylosed vertebræ which follow these are really the anterior caudal vertebræ.

The coccygeal or caudal vertebræ vary in number from eight to ten, and are movable upon one another. In reality, however, the number of caudal vertebræ is much greater than the above, since some of the vertebræ of the anchylosed "sacrum" properly fall to be counted in this region, and the "ploughshare-bone" consists of more than one vertebra. The most noticeable feature about this part of the spinal column is what is known as the "ploughshare-bone" or "pygostyle." This is the last joint of the tail, and is a long, slender, ploughshare-shaped bone, destitute of lateral processes, and without any medullary canal (fig. 405, B). In reality it consists of two or more of the caudal vertebræ, completely anchylosed, and fused into a single mass. It is usually set on to the extremity of the spine at an angle more or less nearly perpendicular to the axis of the body; and it affords a firm basis for the support of

the great quill-feathers of the tail ("rectrices"). It also supports the coccygeal oil-gland, and can be raised at pleasure, so as to meet the bill, when the operation of preening is in progress. In the Ratite Birds, which do not fly, the terminal joint of the tail is not ploughshare-shaped. In the extraordinary Jurassic bird, the *Archæopteryx macrura*, there is no ploughshare-bone, and the tail consists of twenty separate vertebræ, all distinct from one another, and each carrying a pair of quill-feathers, one on each side (fig. 409). As the vertebræ of the ploughshare-bone are distinct from one another in the embryos of existing birds, the tail of the *Archæopteryx* is to be regarded as a case of the permanent retention in the adult of an embryonic character. In the increased number of caudal vertebræ, however, and in some other characters, the tail of the *Archæopteryx* makes a decided approach to the true Reptiles.

The various bones which compose the *skull* of Birds become

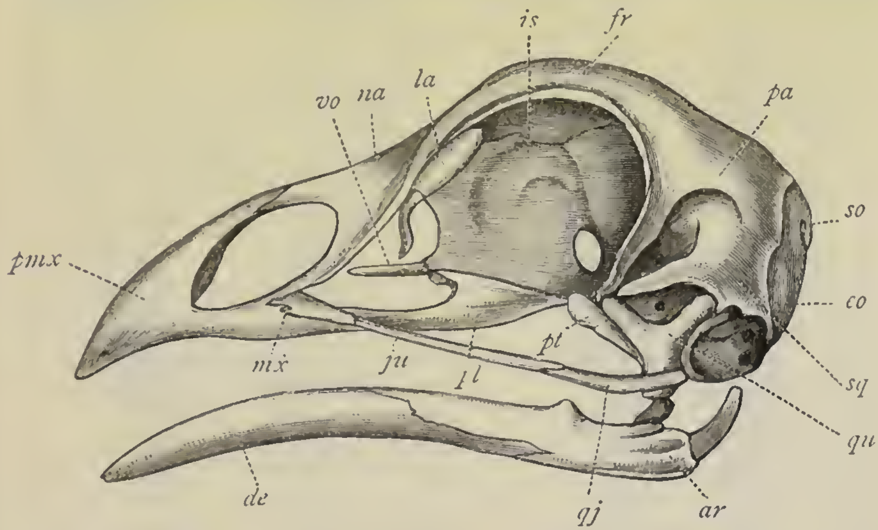

Fig. 400.—Side view of the skull of the Fowl. *de* Dentary portion of the mandible; *ar* Articular portion of the mandible; *qu* Quadrate bone; *sq* Squamosal; *eo* Ex-occipital; *so* Supra-occipital; *pa* Parietal; *fr* Frontal; *la* Lachrymal; *na* Nasal; *vo* Vomer; *pmx* Præmaxilla; *mx* Maxilla; *ju* Jugal; *qj* Quadrato-jugal; *pt* Pterygoid; *pl* Palatine; *is* Interorbital septum.

at an early period of life more or less completely amalgamated, even the sutures between them being obliterated. The skull articulates with the vertebral column by a single hemispherical or globular condyle, carried upon the basioccipital and ex-occipitals. The orbits are of large size, and separated by an interorbital septum, which is often not completely ossified. The facial region is long, and the nasal bones (fig. 400, *na*) are short, so that the external nostrils (except in *Apteryx*) are

placed far back. The lachrymal bone (fig. 400, *la*) is usually a large and distinct bone, articulating with the frontal and nasal bones.

The "beak," which forms such a conspicuous feature in all birds, consists of an upper and lower half (the "superior" and "inferior mandible" of ornithologists). The upper half of the beak is composed principally of the greatly elongated and coalescent præmaxillæ (fig. 400, *pmx*), which give off long

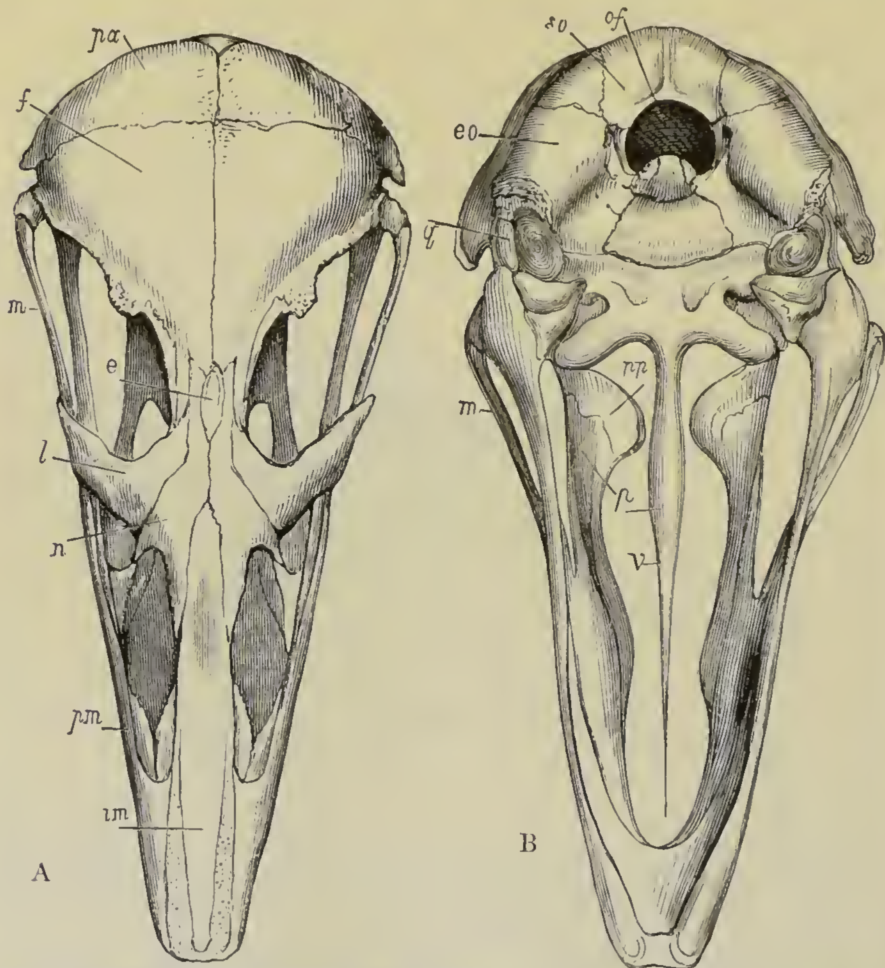

Fig. 401.—Skull of young Ostrich, viewed from above (A), and from below (B). (After Owen.) *of* Occipital foramen; *so* Supra-occipital; *eo* Exoccipital; *q* Quadrate; *pa* Parietal; *pp* Pterygoid process; *f* Frontal; *e* Ethmoid; *n* Nasal; *pm* Maxillary process of præmaxilla; *m* Malar or jugal bone; *im* Præmaxilla; *p* Palatine bone; *v* Vomer; *l* Lachrymal bone. The skull being that of a young bird, the sutures are not yet obliterated.

"frontal processes" above, while they send inwards "palatine processes," and join the small maxillæ behind. The primitively complex mandible has all its constituent pieces fused

with one another, and the two rami are also joined by a bony symphysis, so that the mandible forms a single piece. The mandible is articulated with the skull by the intervention of a quadrate bone (fig. 400, *qu*), which is always permanently movable, and is never anchylosed with the skull. Articulated with the front face of the quadrate bone is a slender bony rod formed behind by the "quadrato-jugal," in the middle by the "jugal" bone, and in front by the maxilla (fig. 400, *qj*, *ju*, *mx*). When the mandible is depressed, the quadrate bone is thrust forward, and the rod formed by the coalescent quadrato-jugal and jugal pushes on the maxilla, thus elevating the upper half of the beak, which is commonly articulated with the skull in a more or less movable manner. The Parrots possess this movable articulation of the upper half of the beak in its greatest perfection, but it exists in a less complete form in many birds.

The maxillæ of birds, as before remarked, are comparatively slender bones; but they send inwards extensively developed horizontal processes ("maxillo-palatine processes"), which may form a large portion of the hard palate. The extent, however, to which these processes are developed varies much in different birds, and on these variations, combined with the structure of the vomer, Prof. Huxley has proposed to found the following divisions of Carinate Birds :—

1. *Desmognathæ.*—Maxillæ sending inwards largely developed maxillo-palatine processes, which unite with one another to form a bony roof to the palate. The vomer truncated in front, small or obsolete. *Ex.* Birds of Prey, Parrots, Cuckoos, Kingfishers, Trogons, Anserine Birds, Storks, Cormorants.

2. *Schizognathæ.*—Maxillo-palatine processes of the maxillæ separated by a wider or narrower cleft. Vomer long and pointed in front, narrow behind. *Ex.* Plovers, Gulls, Penguins, Cranes, Fowls, Sand-grouse, Pigeons.

3. *Ægithognathæ.*—Maxillo-palatine processes separated by a cleft. Vomer truncated in front, narrow behind. *Ex.* Perching Birds, Swifts, Woodpeckers.

4. *Dromæognathæ.*—Vomer broad behind, interposing between the pterygoids, the palatine bones, and the basi-sphenoid rostrum. This division includes only the Tinamous (*Tinamomorphæ*).

In no living Birds are *teeth* ever developed, though rudiments of teeth have been recognised in the embryos of some Parrots. In existing birds the præmaxillæ, maxillæ, and mandible are sheathed in horn, constituting the "beak." In the extinct *Odontornithes*, on the other hand, as also in *Archæopteryx*, conical teeth are present, sunk in distinct sockets or in a groove in the jaw.

The thoracic cavity is bounded behind by the dorsal vertebræ, which are usually, as before said, anchylosed with one another to a greater or less extent. Laterally, the thorax is bounded by the ribs, which vary in number from six to ten pairs. In all birds, certain of the ribs carry a peculiar process —the "uncinate process"—which arises from its posterior margin, is directed upwards and backwards, and passes over the rib next in succession behind, where it is bound down by ligament (fig. 403, B). The first and last dorsal ribs carry no uncinate processes, and in some cases the processes continue throughout life as separate pieces. Anteriorly, the ribs articulate at an obtuse angle with a series of straight bones, the "sternal ribs," which are in turn movably articulated to the sternum in front, and "are the centres upon which the respiratory movements hinge" (Owen). In front, the thoracic cavity is completed by an enormously-expanded sternum or breast-bone, which in some birds of great powers of flight extends over the abdominal cavity as well, in some cases even nearly reaching the pelvis. The sternum of all the Carinate Birds is characterised by the presence of a greatly-developed median ridge or keel (fig. 403, A), to which are attached the great muscles which move the wings. As a general rule, the size of this sternal crest allows a very tolerable estimate to be formed of the flying powers of the bird to which it may have belonged; and in *Strigops* and some other cases it is very much reduced in size. In the Ratite Birds, again, the sternum is rounded and has no keel. At its anterior angles the sternum exhibits two pits for the attachment of the coracoid bones.

The pectoral arch (figs. 402, 403) consists of a scapula, coracoid, and clavicle on each side. The scapula (*s*) is a narrow elongated bone, which is not flattened out into a broad plate, and carries no transverse ridge or spine. In front, the scapula articulates with the upper end of the coracoid, the two together forming the articulating surface for the head of the humerus. The coracoid bone on each side is always the strongest of the bones forming the scapular arch. Superiorly it articulates with the clavicle and scapula, and forms part of the glenoid cavity for the humerus. Inferiorly each coracoid bone articulates with the upper angle of the sternum. The position of the coracoids is more or less nearly vertical, so that they form fixed points for the action of the wings in their downward stroke. The clavicles (fig. 403, A, *c*) are rarely rudimentary or absent, and are in some few cases separate bones. In the great majority of birds, however, the clavicles are anchylosed together at their anterior extremities, so as to

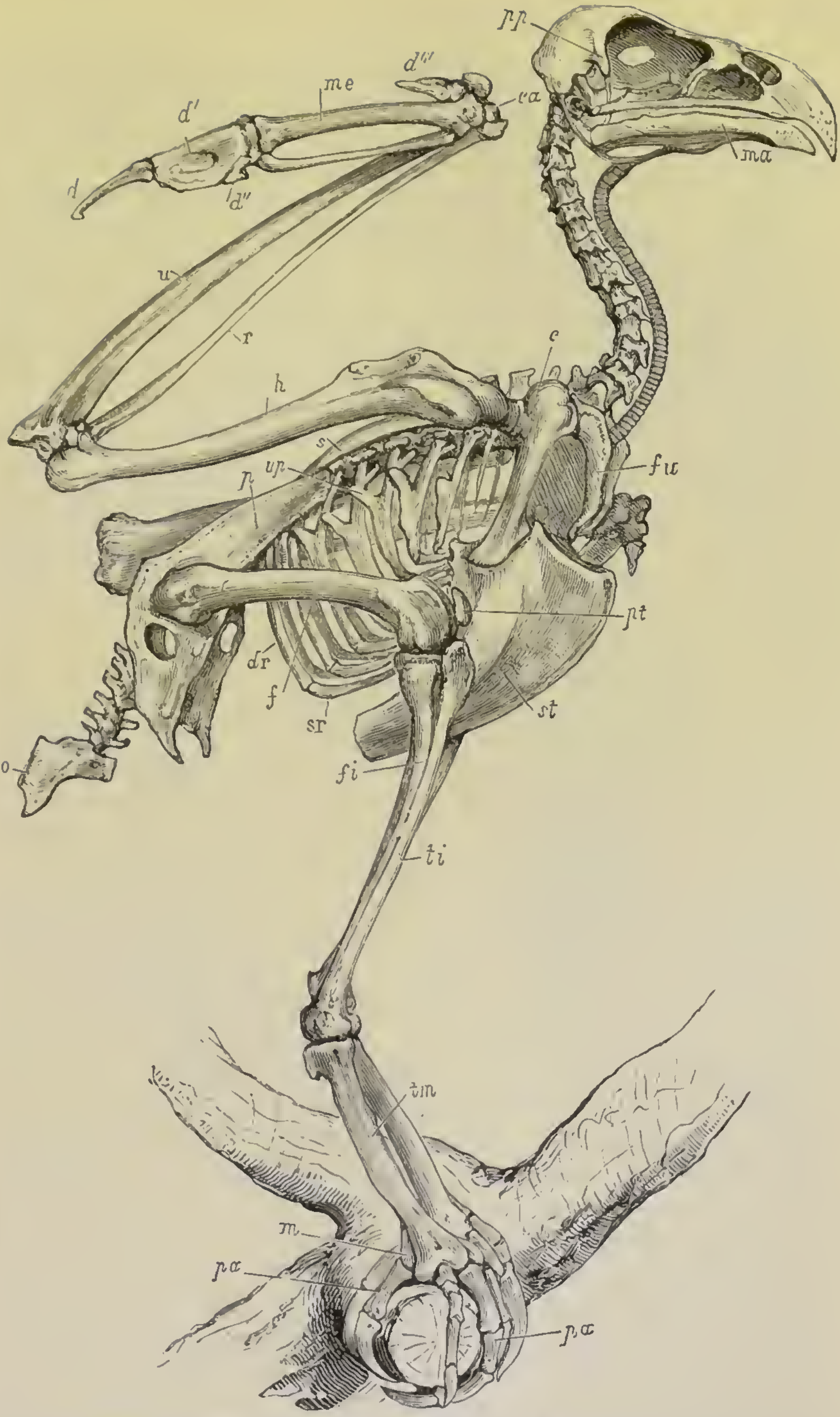

Fig. 402.—Skeleton of Eagle, reduced in size. (After Milne-Edwards.) *p* Ilium; *co* Ploughshare-bone; *dr* Vertebral rib; *sr* Sternal rib; *up* Uncinate process; *st* Sternum; *f* Femur; *fi* Fibula; *ti* Tibia; *pt* Patella; *tm* Tarso-metatarsus; *m* Free metatarsal of the hallux; *pa*, *pa* Phalanges of the hallux and anterior toes; *fu* Furcula; *c* Coracoid bone; *s* Scapula; *h* Humerus; *r* Radius; *u* Ulna; *ca* Carpus; *mc* Metacarpus; *d'* First phalanx of the index finger; *d* Second phalanx of the same; *d''* Middle finger; *d'''* Pollex.

form a single bone, somewhat V-shaped, popularly known as the "merry-thought," and technically called the "furcula" or "furculum" ("fourchette" of the French). The outer extremities of the furcula articulate with the coracoid; and the anchylosed angle is commonly united by ligament or by bone to the top of the sternal keel. The function of the clavicular or furcular arch is "to oppose the forces which tend to press the humeri inwards towards the mesial plane, during the downward stroke of the wing" (Owen). Consequently the clavicles are stronger, and their angle of union is more open, in proportion to the powers of flight possessed by each bird. The clavicles remain distinct in the Emeu, some Parrots, and some Owls; and they are absent in the *Apteryx* and some of the Parrots.

We have next to consider the structure of the bones which compose the fore-limb or "wing" of the bird; and as this organ is the one which chiefly conditions the peculiar life of the bird, it is in it that we find some of the most characteristic points of structure in the whole skeleton. Though considerably modified to suit its function as an organ of aerial progression, the wing of the bird is readily seen to be homologous with the arm of a man or the fore-limb of a Mammal (figs. 402 and 403). The upper arm (*brachium*) is supported by a single bone, the humerus (fig. 403, *h*), which is short and strong, and articulates above with a glenoid cavity, formed partly by the scapula and partly by the coracoid. The humerus is succeeded distally by the fore-arm (*antibrachium*), constituted by the normal two bones, the radius and ulna (*r*, *u*), of which the radius is the smaller and more slender, and the ulna the larger and stronger. The ulna and radius are followed inferiorly by the bones of the wrist or carpus; but these are reduced in number to *two* small bones, one radial and one ulnar, "so wedged in between the antibrachium and metacarpus as to limit the motions of the hand to those of abduction and adduction necessary for the folding up and expansion of the wing; the hand is thus fixed in a state of pronation; all power of flexion, extension, or of rotation, is removed from the wrist joint, so that the wing strikes firmly, and with the full force of the contraction of the depressor muscles, upon the resisting air" (Owen). The two free carpals, which alone remain, belong to the proximal row of the carpus. In the embryo, however, two distal carpals are present, but these unite at an early period with the proximal ends of the metacarpals. There are only three persistent metacarpals, the outermost of the normal five being wanting in the adult; and

the three which remain are, in all living birds, anchylosed with one another and with the distal carpals to form a single bone (figs. 402, *mc*, 403, *m*). This bone, however, appears externally as if formed of *two* metacarpals united to one another at their extremities, but free in their median portion. The metacarpal bone which corresponds to the radius is always the larger of the two (as being really composed of two metacarpals), and it carries the digit which has the greatest number of phalanges. This digit corresponds with the "index" finger, and it is composed of two, or sometimes three,

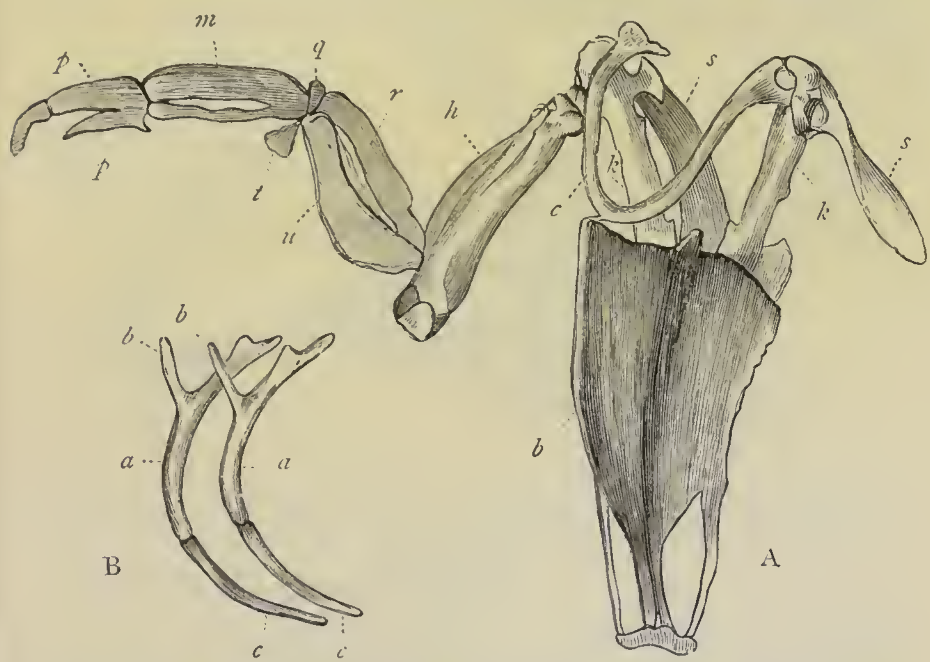

Fig. 403.—A, Breast-bone, shoulder-girdle, and fore-limb of Penguin (after Owen): *b* Sternum, with the sternal keel; *s s* Scapulæ; *k k* Coracoid bones; *c* Furcula or merry-thought, composed of the united clavicles; *h* Humerus; *u* Ulna; *r* Radius; *t* Thumb; *m* Metacarpus; *p p* Phalanges of the fingers; *q* Carpus. B, Ribs of the Golden Eagle: *a a* Ribs giving off (*b b*) uncinate processes; *c c* Sternal ribs.

phalanges (fig. 403, *p*). At the proximal end of this metacarpal, at its outer side, there is generally attached a single phalanx, constituting the so-called "thumb" (fig. 403, *t*), which carries the "bastard-wing," and is sometimes furnished with a claw. The digit which is attached to the ulnar metacarpal corresponds to the middle finger, and very rarely consists of more than a single phalanx (fig. 403). In the Apteryx and the Cassowary there is only one complete digit to the hand.

As regards the structure of the posterior extremity or hind-

limb, the pieces which compose the innominate bones (namely, the ilium, ischium, and pubes) are always anchylosed with one another; and the two innominate bones are also always anchylosed, by the medium of the greatly-elongated ilia, with the sacral region of the spine. In no living bird, however, with the single exception of the Ostrich, are the innominate bones united in the middle line in front by a symphysis pubis. The stability of the pelvic arch necessary in animals which support the weight of the body on the hind-limbs alone, is amply secured in all ordinary cases by the anchylosis of the ilia with the sacrum. The pelvis of birds is remarkable for the great elongation of the ilia (fig. 404, *Il*), which extend almost as far

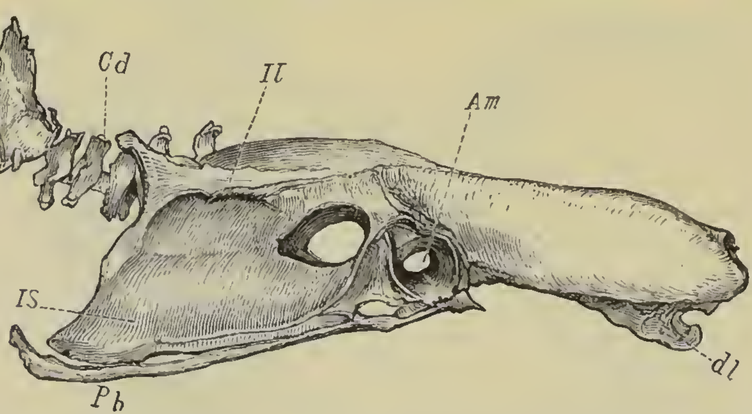

Fig. 404.—Side view of the right side of the pelvis of an adult Fowl, reduced in size. (After W. K. Parker.) *Il* Ilium; *Is* Ischium; *Pb* Pubis; *dl* Dorso-lumbar vertebræ; *Cd* Caudal vertebræ; *Am* Acetabulum, with its perforated floor.

behind the acetabulum as they do in front of it. The ischium and pubis extend backwards, nearly parallel with the axis of the ilium, the latter (fig. 404, *Pb*) being a slender curved bone, and neither of them uniting with the sacrum. The floor of the articular cavity (acetabulum) into which the head of the femur is received is incompletely ossified, and exhibits a larger or smaller perforation (fig. 404, *Am*).

As in the higher Vertebrates, the lower limb (fig. 405, A) consists of a femur, a tibia and fibula, a tarsus, metatarsus, and phalanges; but some of these parts are considerably obscured by anchylosis. The femur or thigh-bone (fig. 405, A, *f*) is very short, comparatively speaking. A "patella," or sesamoid bone in the tendon of the extensor muscle of the leg, is developed. The chief bone of the leg is the tibia (*t*), to which a thin and tapering fibula (*r*) is anchylosed. The upper end of the fibula, however, articulates with the external condyle of the femur. The ankle-joint is placed, as in Reptiles,

between the proximal and distal portions of the tarsus. The proximal portion of the tarsus, representing apparently the astragalus and calcaneum, becomes undistinguishably amalgamated with the lower end of the tibia, which latter bone is therefore best spoken of as the "tibio-tarsus." The distal row of tarsal bones becomes anchylosed with the second, third, and fourth metatarsals to constitute the most character-

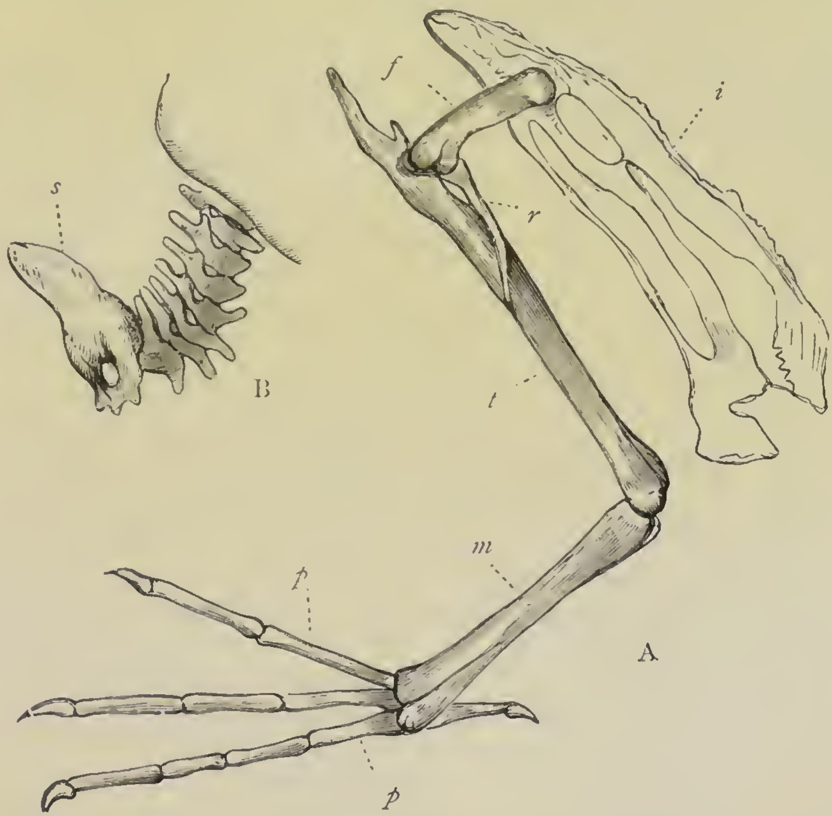

Fig. 405.—A, Hind-limb of the Loon (*Colymbus glacialis*)—after Owen: *i* Innominate bone; *f* Thigh-bone or femur; *t* Tibia, with the proximal portion of the tarsus anchylosed to its lower end; *r* Fibula: *m* Tarso-metatarsus, consisting of the distal portion of the tarsus anchylosed with the metatarsus; *p p* Phalanges of the toes. B, Tail of the Golden Eagle; *s* Ploughshare-bone, carrying the great tail-feathers.

istic bone in the leg of the Bird—the "tarso-metatarsus" (*m*). In most of the long-legged birds, such as the Waders, the disproportionate length of the leg is given by an extraordinary elongation of the tarso-metatarsus. The lower end of the tarso-metatarsus terminates in three articular surfaces for the second, third, and fourth digits of the foot (when these are present). The first metatarsal, corresponding with the hallux, is not fused with the tarso-metatarsus, but is generally present as a free bony spine, placed at the distal end of the tarso-meta-

tarsus, and joined to it by ligament. Parker has shown that a proximal rudiment of the first metatarsal is present as well in the embryo.

The tarso-metatarsus is followed inferiorly by the digits of the foot. In most birds the foot consists of three toes directed forwards and one backwards—four toes in all. In no wild bird are there *more* than four toes,* but often there are only three, and in the Ostrich the number is reduced to two. In all birds which have three anterior and one posterior toe, it is the posterior thumb or *hallux* (that is to say, the innermost digit of the hind-limb) which is directed backwards; and it invariably consists of *two* phalanges only, its metatarsal, as above mentioned, being incomplete and united as a rule to the tarso-metatarsus by ligament only. The most internal of the three anterior toes (the "index") consists of three phalanges; the next ("middle") has four phalanges; and the outermost toe ("annularis") is made up of five phalanges (fig. 405, A). This increase in an arithmetical ratio of the phalanges of the toes, in proceeding from the inner to the outer side of the foot, obtains in most birds, and enables us readily to detect which digit is suppressed, when the normal four are not all present. In no bird, living or extinct, is the fifth or outermost toe developed. Variations of different kinds exist, however, in the number and disposition of the toes. In many birds—such as the Parrots—the outermost toe is turned backwards, so that there are two toes in front and two behind, whilst in the Trogons the inner toe is turned back with the hallux, and the outermost toe is turned forwards. In others, again, the outer toe is normally directed forwards, but can be turned backwards at the will of the animal. In the Swifts, on the other hand, all four toes are present, but they are all turned forwards. In many cases—especially amongst the Natatorial birds—the hallux is wholly wanting, or is rudimentary. In the Emeu, Cassowary, Bustards, and other genera, the hallux is invariably absent, and the foot is three-toed. In the Ostrich both the hallux and the next toe ("index") are wanting, and the foot consists simply of two toes, these being the third and fourth digits.

The *digestive system* of birds comprises the beak, tongue, gullet, stomach, intestines, and cloaca. Teeth are invariably wanting in living birds, and the jaws are encased in horn,

* In some of the domestic breeds of the Fowl there is an additional toe developed, making the foot five-toed; but the supernumerary digit is on the *inner* side of the foot, and does not represent the fifth or little toe.

constituting the bill. In the extinct *Odontopteryx* the osseous substance of the jaws is prolonged into tooth-like processes of two sizes; and in the *Odontornithes* of the Cretaceous period the jaws are furnished with true teeth implanted in distinct sockets. The form of the bill varies enormously in different birds, and it is employed for holding and tearing the prey, for prehensile purposes, for climbing, and in some birds as an organ of touch. In these last-mentioned cases the bill is more or less soft, and is supplied with filaments of the fifth nerve. In many birds, too, in which the bill is not soft, the base of the upper mandible is covered by a patch of naked skin, constituting what is called the "cere," and this, no doubt, serves also as a tactile organ.

The tongue of birds can hardly be looked upon as an organ of taste, since it is generally cased in horn, like the mandibles. It is, in fact, principally employed as an organ of prehension; but in some cases—as in the Parrots—it is soft and fleshy, and then, doubtless, is to some extent connected with the sense of taste. It is essentially composed of a prolongation of the hyoid bone (the glosso-hyal), which is sheathed in horn, and is variously serrated or fringed.

Salivary glands are invariably present, but they are rarely of large size (they are very large in the Woodpeckers and Swifts), and they have often a very simple structure.

In accordance with the structure of the neck, the gullet in birds is usually of great length, and it is generally very dilatable. In general the œsophagus is dilated inferiorly into a pouch, which is situated at the lower part of the neck, just in front of the merry-thought. This is known as the "crop" or "ingluvies" (fig. 406, *in*), and it may either be a mere dilatation of the tube of the gullet, or it may be a single or double pouch. The food is detained in the crop for a longer or shorter time, according to its nature, before it is subjected to the action of the proper digestive organs. The œsophagus, after leaving the crop, shortly opens into a second cavity, which is known as the "proventriculus" or "ventriculus succenturiatus" (*pr*). This is the true digestive cavity, and its mucous membrane is richly supplied with gastric follicles which secrete the gastric juice. The proventriculus, however, corresponds, not with the whole stomach of the Mammals, but only with its cardiac portion; and it opens into a second muscular cavity (gizzard), which corresponds to the pyloric division of the Mammalian stomach. The gizzard (*gi*) is situated below the liver, and forms an elongated sac, having two apertures above, of which one conducts into the duodenum, or com-

mencement of the small intestine, whilst the other communicates with the proventriculus. The two chief forms of gizzard are exhibited respectively by the Raptorial Birds, which feed on easily-digested animal food, and those birds which, like Fowls, Pigeons, and the game birds generally, feed on hardly-digested grains. In the Birds of Prey the gizzard scarcely deserves the name, being, as a rule, nothing more than a wide membranous cavity with thin walls. In the granivorous birds, whose hard food requires crushing, the gizzard is enormously developed; its lining coat is formed of a thick, horny epithelium, and its walls are extremely thick and muscular. This constitutes a grinding apparatus, like the stones of a mill; whilst the "crop" or œsophageal dilatation may be compared to the "hopper" of a mill, since it supplies to the gizzard "small successive quantities of food as it is wanted" (Owen). Supplementing the action of the muscular walls of the gizzard, and acting in the place of teeth, are the small stones or pebbles, which, as is so well known, so many of the granivorous birds are in the habit of swallowing with their food, or at other times. A pyloric valve may or may not be present, and is often wanting in birds living on grains or fruit.

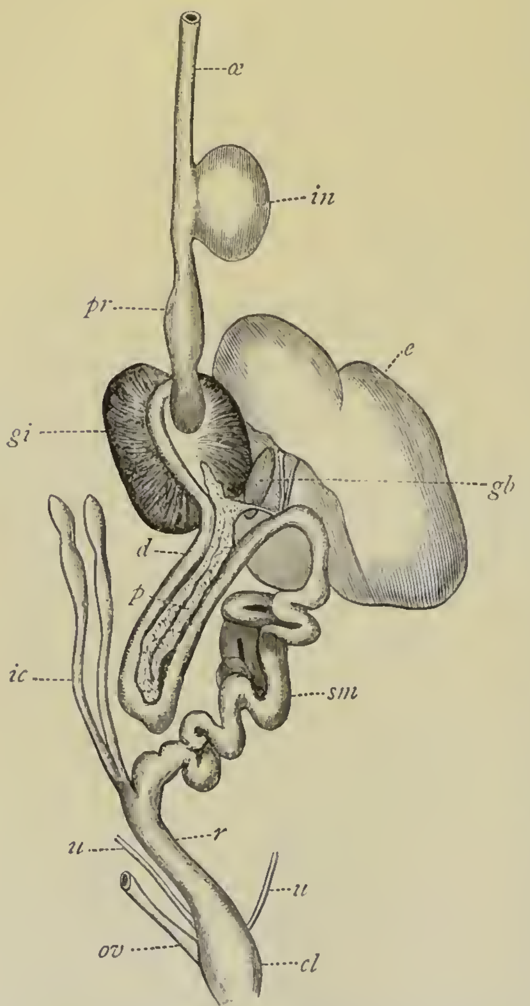

Fig. 406.—Alimentary canal of a Fowl. *æ* Œsophagus; *in* Crop; *pr* Proventriculus; *gi* Gizzard; *d* Duodenum; *sm* Lower part of small intestine; *ic* Intestinal cæca; *r* Rectum; *cl* Cloaca; *l* Liver; *gb* Gall-bladder; *p* Pancreas; *u u* Ureters; *ov* Left oviduct (the right oviduct is rudimentary).

The intestinal canal extends from the gizzard to the cloaca, and is, comparatively speaking, short. The secretions of the

liver and pancreas are poured into the small intestine, as in Mammals. A gall-bladder is usually present, but is sometimes wanting (Parrots, Pigeons, &c.). The commencement of the large intestine is generally provided with a pair of "cæca" or blind tubes, the length of which varies a good deal in different birds (fig. 406, *ic*). They are sometimes wanting (Parrots, &c.), or there may be only one; and their exact function is uncertain; though they are most probably connected partly with digestion and partly with excretion. The large intestine is always very short—seldom more than a tenth part of the length of the body—and it terminates in the "cloaca" (fig. 406, *cl*). This is a cavity which in all birds receives the termination of the rectum, the ducts of the generative organs, and the ureters; and serves, therefore, for the expulsion of the fæces, the generative products, and the urinary secretion.

Respiration is effected in Birds more completely and actively than in any other class of the *Vertebrata*, and as the result of this, their average temperature is also higher. This extensive development of the respiratory process is conditioned by the fact that air is admitted not only into the lungs, but also into a greater or less number of the bones, and into a number of cavities—the so-called air-receptacles—which are distributed through various parts of the body, and which are present in all birds except the *Apteryx*. By this extensive penetration of air into various parts of the body, the aeration of the blood is effected not only in the lungs, but also over a greater or less extent of the systemic circulation as well; and hence in Birds this process attains its highest perfection. The cavities of the thorax and abdomen are not separated from one another by a complete partition, the diaphragm being mostly only present in a rudimentary form. The lungs are two in number, of a bright-red colour, and spongy texture. They are confined to the back of the thorax, extending along each side of the spine, from the second dorsal vertebra to the kidney. They differ from the lungs of the Mammals in not being freely suspended in a pleural membrane. The pleura, on the other hand, is reflected only over the anterior surface of the lungs. The bronchi, or primary divisions of the windpipe (fig. 407), diminish in size as they pass through the lung, by giving off branches, which in turn give off the true air-vesicles of the lung. When the bronchial tubes reach the surface of the lung, they open, by a series of distinct apertures, into a series of "air-sacs." These are a series of membranous sacs formed by the continuation of the lining membrane of the bronchi, and supported by reflections of the serous membrane of the thora-

cico-abdominal cavity. There are nine proper air-sacs—two abdominal (the only ones present in some birds, such as the Penguin), two in the hinder part of the thorax, two in the front part of the thorax, two on the sides of the neck, and one between the branches of the furcula. The air-cells not only reduce the specific gravity of birds, and thus fit them for an aerial life, but also assist in the mechanical work of respiration, and must also greatly promote the aeration of the blood.

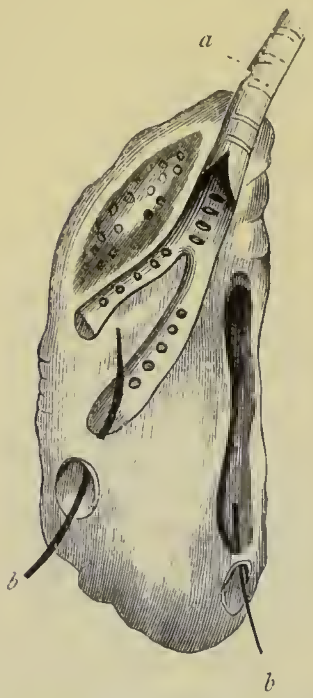

Fig. 407.—Lung of Goose (after Owen). *a* Main bronchus dividing into secondary branches as it enters the lung, these giving off smaller branches, the openings of which are seen on the back of the bronchial tubes; *b b* Bristles passed from the bronchi through the apertures on the surface of the lung by which the bronchi communicate with the air-receptacles.

In connection with the air-receptacles, and as an extension of them, is a series of cavities occupying the interior of a greater or less number of the bones, and also containing air. In young birds these air-cavities do not exist, and the bones are filled with marrow, as in the Mammals. The extent, also, to which the bones are "pneumatic" varies greatly in different birds. In the Penguin—which does not fly—all the bones contain marrow, and there are no air-cavities. In the Ratite Birds (Ostrich, &c.) the pneumaticity of the bones is greatly diminished, air being admitted to some of the cranial bones, and in general to the femur, but the majority of the bones being filled with marrow. On the other hand, in some cases (Pelican, Gannet, Hornbill, &c.) almost all the bones of the skeleton are pneumatic, even the very phalanges of the toes in some cases having the air admitted to their interior. The functions discharged by the air-cavities of the bones appear to be much the same as those of the air-receptacles—namely, that of diminishing the specific gravity of the body and subserving the aeration of the blood.

The *heart* in all Birds is four-chambered, the right and left sides of the heart being completely separated from one another, and no direct communication taking place between the systemic and pulmonary circulations. The venous blood is

returned from the body to the right auricle by two superior venæ cavæ (as in Reptiles) and a single inferior vena cava. The right auriculo-ventricular opening is protected by a strong muscular valve, and the right ventricle is thin-walled, and wraps partially round the left ventricle. The right ventricle propels the venous blood to the lungs through the pulmonary artery, the base of which is furnished with semilunar valves. After aeration, the blood is returned to the left auricle by the pulmonary veins, and then is driven into the thick-walled left ventricle. From this arises the systemic aorta, which turns over the right bronchus, the left aorta not being developed. The aorta divides almost immediately above its origin into the right and left innominate arteries, and is continued below the spine as the dorsal aorta.

In accordance with their extended respiration and high muscular activity, the complete separation of the greater and lesser circulations, and the perfect structure of the heart, Birds maintain a higher average temperature than is the case with any other class of the *Vertebrata*. This result is also to a considerable extent conditioned by the non-conducting nature of the combined down and feathers which form the integumentary covering of Birds.

The elongated, generally three-lobed *kidneys* lie in the hollows on either side of the front of the "sacrum." The ureters open, along with the ducts of the generative glands, into a kind of pouch (urogenital chamber) of the dorsal wall of the cloaca. The urine is semi-solid, containing a large amount of urates.

As regards the *reproductive organs*, the males have two testes placed above the upper extremities of the kidneys, and their efferent ducts (*vasa deferentia*) open into the cloaca alongside of the ureters. A male organ (*penis*) may or may not be present, but there is no perfect urethra. The female bird is provided with only one ovary and oviduct—that of the left side—the corresponding organs of the right side being rudimentary or absent. The oviduct is very long and tortuous, and the egg, during its passage through it, receives the albuminous covering which serves for the nutrition of the embryo, and which is known as the "white" of the egg. The lower portion of the oviduct is dilated, and the egg receives here the calcareous covering which constitutes the "shell." Finally, the oviduct debouches into the cloaca, into which the egg, when ready, is expelled. The further development of the chick is commonly secured by the process of "incubation" or brooding, for which birds are peculiarly adapted, in consequence of the high temperature of their bodies.

The ovum of Birds is of relatively very large size, and not only is impregnation internal, but segmentation of the yolk is completed before the egg is laid. When development has proceeded so far that external life is possible, the chick makes an aperture in the shell by which it escapes, the tip of the upper mandible being provided for this purpose with a temporary calcareous knob, which subsequently disappears. The state of the young upon exclusion from the egg is very different in different cases. In some groups of Birds (*Aves præcoces*) the young bird is covered with down, and is able to run about and help itself from the moment of its liberation from the egg. In other cases, again (*Aves altrices*), the young are born in a naked and helpless state, and require to be brooded over and fed by the parents for a longer or shorter time after exclusion from the egg. There are, however, cases (*e.g.*, the Herons) in which the young are covered with down when born, but are nevertheless quite helpless for some time after hatching.

The *brain* of Birds is relatively larger than that of Reptiles, especially as regards the size of the cerebrum. The cerebral hemispheres do not extend backwards over the cerebellum, but they cover the mid-brain. The surface of the hemispheres is devoid of convolutions, and the corpus callosum is not developed. The optic lobes are of large size, and are laterally displaced. The cerebellum is not so highly developed as in Mammals, there being no pons Varolii, but rudimentary lateral lobes (flocculi) are present.

As regards the *organs of the senses*, the eyes are always well developed, and in no bird are they ever rudimentary or absent. The chief peculiarity of the eye (fig. 408) is that the cornea forms a segment of a much smaller sphere than does the eyeball proper, so that the anterior part of the eye is obtusely conical, whilst the posterior portion is spheroidal. Another peculiarity is that the form of the eye is maintained by a ring of from thirteen to twenty bony plates, which are placed in the anterior portion of the sclerotic coat. The structure known as the "pecten" (fig. 408, *i*) is a peculiar vascular fold of the choroid which projects into the eyeball from its hinder wall, and which is folded longitudinally like a fan. It is very rarely wanting (*Apteryx*), but its use is not known. Besides the upper and lower eyelids, Birds possess the "third eyelid" or "membrana nictitans." This is a membranous fold, sometimes pearly-white, sometimes more or less transparent, which is placed internal to the proper eyelids on the inner side of the eye, over the anterior surface of which it can be drawn

like a curtain, moderating a too great intensity of light. As to the organ of hearing, most birds possess no external ear or "auricle," by which sounds can be collected and transmitted to the internal ear. In some birds, however, as in the Ostrich and Bustard, the external meatus auditorius is surrounded by a circle of feathers, which can be raised and depressed at will. The Owls, also, have the external meatus auditorius protected by a musculo-membranous valve, which foreshadows the external ear of the majority of Mammals. The external nostrils in Birds are usually placed on the sides of the upper mandible, near its base, in the form of simple perforations, which sometimes communicate from side to side by the deficiency of the septum narium. In the singular *Apteryx* of New Zealand, the nostrils are placed at the extreme end or tip of the elongated upper mandible. Sometimes the nostrils are defended by bristles, and sometimes by a scale (*Gallinæ*). Taste must be absent, or almost absent, in the great majority of birds, the tongue being nothing more than a horny sheath surrounding a process of the hyoid bone, and serving for deglutition or to seize the prey. In the Parrots, however, the tongue is thick and fleshy, and some perception of taste may be present. Touch or tactile sensibility, too, as already remarked, is very poorly developed in Birds. The body is entirely, or almost entirely, covered with feathers; the anterior limbs are converted into wings, and rendered thereby useless as organs of touch; and the posterior limbs are covered with horny scales or feathers. The bill, certainly, officiates as an organ of touch, but it cannot possess any acute sensibility, as in most birds it is encased in a rigid horny sheath. In some birds, however, such as the common Duck, the texture of the bill is moderately soft, and it is richly supplied with filaments of the fifth nerve; so that in these cases the bill doubtless constitutes a tolerably efficient tactile organ. The "cere," too, or the fleshy scale found at the base of the bill in some birds, is in all probability also used as a tactile organ.

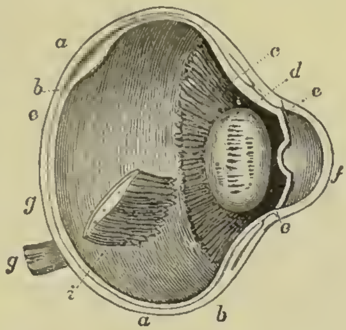

Fig. 408.—Section of the eye of a Bird (after Macgillivray). *aa* Sclerotic; *bb* Choroid; *c* Ciliary muscle; *d* Lens; *ee* Iris; *f* Cornea; *g* Optic nerve; *i* Pecten.

The last anatomical peculiarity of Birds which requires notice is the peculiar apparatus known as the "inferior larynx," or "syrinx," by which the song of the singing birds is con-

ditioned. "The air-passages of birds commence by a simple *superior larynx*, from which a long *trachea* extends to the anterior aperture of the thorax, where it divides into the two *bronchi*, one for each lung. At the place of its division, there exists in most birds a complicated mechanism of bones and cartilages, moved by appropriate muscles, and constituting the true organ of voice; this part is termed the *inferior larynx*" (Owen). The inferior larynx may be developed from the trachea only, before the division of this tube into the bronchi; or it may be developed wholly from the bronchi; or, lastly, and more commonly, it may be developed at the junction of the trachea and bronchi and out of both. The structure of the vocal apparatus is complicated, and there is no necessity for entering upon it here. It is to be remembered, however, that those modifications of the voice which constitute the song of birds, are produced in a special and complex cavity placed at or near the point where the trachea divides into the two bronchi, and *not* in a true larynx situated at the summit of the windpipe. The syrinx is wanting in a few birds (*e.g.*, the *Ratitæ*). Lastly, the trachea of birds is always of considerable proportionate length, and it is often twisted or dilated at intervals, this structure, doubtless, having something to do with the production of vocal sounds.

Before passing on to the consideration of the divisions of Birds, a few words may be said as to the *migration* of birds. In temperate and cold climates comparatively few birds remain constantly in the same region in which they were hatched. Those which do so remain are called "permanent birds" (*aves manentes*). Other birds, such as the Woodpeckers, wander about from place to place, without having any fixed direction. These are called "wandering birds" (*aves erraticæ*), and their irregular movements are chiefly conditioned by the scarcity or abundance of food in any particular locality. Other birds, however, at certain seasons of the year undertake long journeys, usually uniting for this purpose into large flocks. These birds—such as the Swallows, for instance—are properly called "migratory birds" (*aves migratoriæ*). The movements of these birds are conditioned partly by the necessity that the adult has of finding a region which has a certain mean temperature, and partly because a region which might be sufficiently suitable for the adult might be either too hot or too cold to permit of the young being brought up there. Such birds, therefore, either migrate from cold regions to warmer latitudes on the approach of winter, or, when summer is coming on, they migrate to regions where the temperature is lower.

As regards their *distribution in time*, Birds, from their aerial mode of life, are not so liable to be preserved in the fossil condition as are animals which are essentially aquatic. For this reason, among others, our knowledge of the past history of the Birds is exceedingly imperfect. No remains of Birds have hitherto been found in the Palæozoic rocks. The earliest undoubted fossil bird is the singular and aberrant *Archæopteryx*, the only discovered remains of which (two specimens) have been found in the Jurassic rocks. Towards the close of the Mesozoic period, in the Cretaceous period, Birds not strikingly different from existing types make their appearance, and along with these we meet with the remains of the extraordinary "Toothed Birds," which constitute the division of the *Odontornithes*. The characters of these will be briefly spoken of later on. Lastly, by the time we reach the middle of the Tertiary period, almost all great existing groups of Birds are represented by fossil types. Some of the Tertiary Birds, however, differ widely from any forms now in existence.

CHAPTER LX.

DIVISIONS OF BIRDS.

General Classification. Saurornithes, Odontornithes, and Ratitæ.

Owing to the extreme compactness and homogeneity of the entire class *Aves*, conditioned mainly by their adaptation to an aerial mode of life, the subject of their classification has been one of the greatest difficulties of the systematic zoologist. Even as regards the primary subdivisions, or *sub-classes*, of *Aves*, ornithologists are not in absolute agreement, the subdivision of the *Odontornithes* being rejected by so high an authority as Prof. Newton. With regard to the smaller divisions, or *orders*, of Birds, specialists have not at present agreed upon the acceptance of any one system in preference to others. Most modern ornithologists have abandoned the old orders of Birds as established in the systems of Linnæus, Cuvier, Illiger, and others, the essential basis of which is found in the adaptation of particular groups of Birds to particular modes of life,

and which, artificial as in many respects they undoubtedly are, have the merit of great simplicity. Of the more modern systems, some, like the classifications of Prof. Huxley and Prof. Garrod, are essentially anatomical, and are based upon the observed modifications in different groups of the structure of some particular organ or group of organs. Thus, the system of Prof. Huxley is based essentially upon the structure of the bony palate; while that proposed by Prof. Garrod has as its starting-point the arrangement of the muscles of the hind-limb. Other modern systems are more natural, in so far as they have reference to the entire organisation of the animals classified, and are not based merely upon modifications of some one organ or group of organs; but it is only in their broad outlines that such classifications agree among themselves, and as regards minor subdivisions and nomenclature, there is still great diversity of opinion and practice among high ornithological authorities. In the absence of any universally accepted classification, the following arrangement of the subdivisions of *Aves* will probably be found to be sufficient for the purposes of the ordinary student:—

SUB-CLASS I. SAURORNITHES.—Jaws toothed; metacarpal bones not anchylosed; tail of numerous separate vertebræ, without a "ploughshare-bone." (Extinct.)

Order 1. *Saururæ.—Archæopteryx.*

SUB-CLASS II. ODONTORNITHES.—Jaws toothed; metacarpals wanting, or united; tail not long and lizard-like. (Extinct.)

Order 1. *Odontolcæ.—Hesperornis.*
Order 2. *Odontotormæ.—Ichthyornis.*

SUB-CLASS III. RATITÆ.—Jaws without teeth; metacarpals (when present) united; tail short; sternum raft-like, without a keel; feathers lax, the barbules being destitute of hooks.

Order 1. *Struthiones.*—Ostrich, Rhea, Cassowary, Emeu.
Order 2. *Apteryges.—Apteryx.*

SUB-CLASS IV. CARINATÆ.—Jaws without teeth; metacarpals united; sternum with a more or less prominent keel or "carina"; wing-feathers firm, the barbules being hooked.

Order 1. *Crypturi.*—Tinamou.
Order 2. *Impennes.*—Penguins.
Order 3. *Pygopodes.*—Guillemots, Auks, Grebes, Divers.
Order 4. *Gaviæ.*—Gulls, Petrels.
Order 5. *Steganopodes.*—Frigate-birds, Pelicans, Gannets, Cormorants.
Order 6. *Chenomorphæ.*—Screamers, Ducks, Geese, Swans, Flamingoes.
Order 7. *Herodii.*—Herons, Storks, Spoonbills.
Order 8. *Grallæ.*—Rails, Snipe, Plovers, Bustards, Cranes.
Order 9. *Gallinæ.*—Grouse, Partridges, Pheasants, Fowls, Mound-birds, Curassows, Sand-grouse, Bush-quails.
Order 10. *Columbæ.*—Pigeons, Ground-pigeons, *Didunculus*, Dodo.
Order 11. *Passeres.*—Thrushes, Finches, Swallows, Starlings, &c.

Order 12. *Picariæ.*—Cuckoos, Kingfishers, Bee-eaters, Hoopoe, Toucans, Woodpeckers, Trogons, Swifts, Humming-birds.
Order 13. *Psittaci.*—Parrots and their allies.
Order 14. *Raptores.*—Owls, Falcons, American Vultures, Secretary Vultures.

SAURORNITHES.

SUB-CLASS I. SAURORNITHES.—This sub-class includes the single order *Saururæ*, comprising only the singular extinct genus *Archæopteryx*, and is characterised by the fact that the tail consists of numerous free vertebræ, each carrying a pair of quill-feathers, while the metacarpal bones are not anchylosed with one another, and the jaws are provided with teeth.

ORDER SAURURÆ.—This being the only order included in this sub-class, its characters are necessarily the same as those of the sub-class. The genus *Archæopteryx* comprises, so far as at present known, only a single species, namely, the remarkable *Archæopteryx macrura* of the Lithographic Slates (Juras-

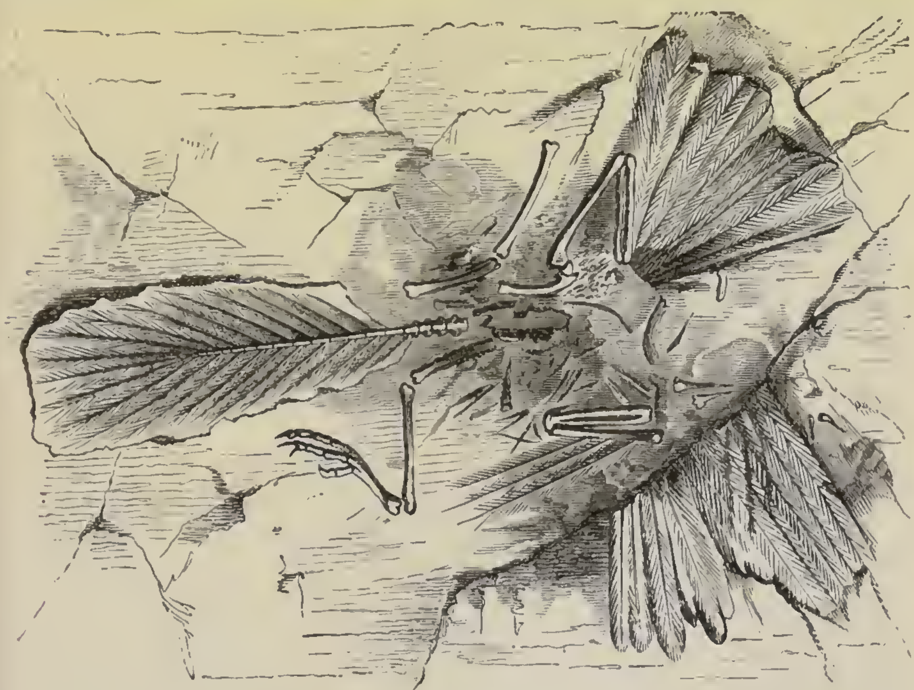

Fig. 409.—*Archæopteryx macrura*, being a reduced representation of the British Museum specimen.

sic) of Solenhofen, of which three specimens (one consisting of a feather only) have hitherto been brought to light. In this exceeding abnormal and very ancient type of the Birds (fig. 409), the tail consists of twenty elongated and free verte-

bræ, each of which carried a pair of quill-feathers. The tail was thus like that of a Lizard, save for its feathers, and there was no ploughshare-bone. The jaws carried conical teeth, though it is not certain how many of these were present, or whether the teeth were in sockets or in a groove. The general structure of the fore-limb was like that of Birds generally, but there were the special peculiarities that the metacarpal bones were not anchylosed with one another, and that all the three digits of the manus carried claws. That *Archæopteryx* possessed the power of flight is shown by the fact that the wings were furnished with well-developed quill-feathers. The three bones composing the pelvic arch on each side appear to have been separate, and the metatarsal bones were also separate or imperfectly united. According to Marsh, the vertebræ are also biconcave. The foot was four-toed, the hallux being turned backwards. *Archæopteryx macrura* seems to have been about as big as a pigeon, and its structural characters are of special interest from the many points in which they show an approach to those of the Deinosaurian Reptiles.

ODONTORNITHES.

SUB-CLASS II. ODONTORNITHES.—This division includes certain remarkable extinct types, of Cretaceous age, and is characterised by the possession of conical teeth in the jaws, the tail being short and bird-like, and the metacarpals either absent (*Hesperornis*) or anchylosed (*Ichthyornis*). The two principal types comprised in this sub-class differ so widely from each other and from all existing Birds, that Professor Marsh has founded the following two orders for their reception :—

ORDER I. ODONTOLCÆ.—This order is characterised by the fact that the teeth are sunk in a groove, the vertebral centra are saddle-shaped, and the sternum has no keel. It includes only the extraordinary *Hesperornis regalis*, from the Cretaceous rocks of North America. In this wonderful fossil we have a gigantic diving-bird somewhat resembling the true "Divers" or "Loons" (*Colymbus*), but having the jaws furnished with numerous conical recurved *teeth*, sunk in a deep continuous groove (fig. 410).

The front of the upper jaw does not carry teeth, and was probably encased in a horny beak. The breast-bone is entirely destitute of a central ridge or keel, and the wings are minute and quite rudimentary; so that *Hesperornis*, unlike *Ichthyornis*, must have been wholly deprived of the power of

flight, in this respect approaching the existing Penguins. The metacarpal bones are wanting. The tail consists of about twelve vertebræ, of which the last three or four are amalgamated to form a flat terminal mass, there being at the same time clear indications that the tail was capable of up and down movement in a vertical plane, this probably fitting it to serve as a swimming-paddle or rudder. The vertebræ of the

Fig. 410.—Skeleton of *Hesperornis regalis*, restored. (After Marsh.) About one-tenth of the natural size.

cervical and dorsal regions are of the ordinary ornithic type. The legs were powerfully constructed, and the feet were adapted to assist the bird in rapid motion through the water. The known remains of *Hesperornis regalis* prove it to have been a swimming and diving Bird, of larger dimensions than any of the aquatic members of the class of Birds with which we are acquainted at the present day. It appears to have

stood between five and six feet high, and its inability to fly is fully compensated for by the numerous adaptations of its structure to a watery life. Its teeth prove it to have been carnivorous in its habits, and it probably lived upon fishes.

ORDER II. ODONTOTORMÆ.—This order is characterised by the fact that the teeth are sunk in separate sockets in the jaw, the vertebral centra are biconcave, and the sternum is carinate, the wings being well developed. This order was founded by Marsh for the reception of two remarkable birds —viz., *Ichthyornis dispar* and *Apatornis celer*, both from the Cretaceous rocks of North America. The skull of the latter not being known, the former may be taken as the type of the order.

The teeth in *Ichthyornis dispar* were sunk in distinct sockets, and were " small, compressed, and pointed, and all of those preserved are similar. Those in the lower jaw number about twenty in each ramus, and are all more or less inclined backwards. . . . The maxillary teeth appear to have been equally numerous, and essentially the same as those in the mandible. The skull was of moderate size, and the eyes placed well forward. The lower jaws are long and slender, and the rami were not closely united at the symphysis. . . . . The jaws were apparently not encased in a horny sheath.

" The scapular arch, and the bones of the wings and legs, all conform closely to the true ornithic type. The wings were large in proportion to the legs, and the humerus had an extended radial crest. The metacarpals were united, as in ordinary birds. The bones of the posterior extremities resemble those of swimming birds. The vertebræ were all biconcave, the concavities at each end of the centra being distinct and nearly alike. Whether the tail was elongated cannot at present be determined; but the last vertebra of the sacrum was unusually large.

" The bird was fully adult, and about as large as a pigeon. With the exception of the skull, the bones do not appear to have been pneumatic, though most of them are hollow. The species was carnivorous, and probably aquatic."—(Marsh.)

RATITÆ.

SUB-CLASS III. RATITÆ.—This sub-class comprises the birds which have been commonly spoken of under the name of *Cursores*, such as the Ostrich, Cassowary, Emeu, &c. The distinguishing characters of the sub-class are that the sternum (fig. 411) is rounded or raft-like, and destitute of a keel (hence

the name *Ratitæ*, from the Latin *rates*, a raft). There is no power of flight, and the clavicles are rudimentary or absent. The barbs of the feathers are disunited, the barbules being without hooks.

The *Ratitæ* include a small number of non-flying birds, mostly of large size, confined, with the exception of the Ostrich, to regions south of the equator. There are five living and a number of extinct genera; but ornithologists are not agreed as to the number of *orders* represented by the comparatively small number of known types. The earliest known remains of Ratite Birds have been found in the Eocene Tertiary deposits (*Dasornis*). The principal types of the *Ratitæ* may be considered under the following heads:—

ORDER I. STRUTHIONES.—The members of this order are Ratite birds in which the foot is three-toed or two-toed, and

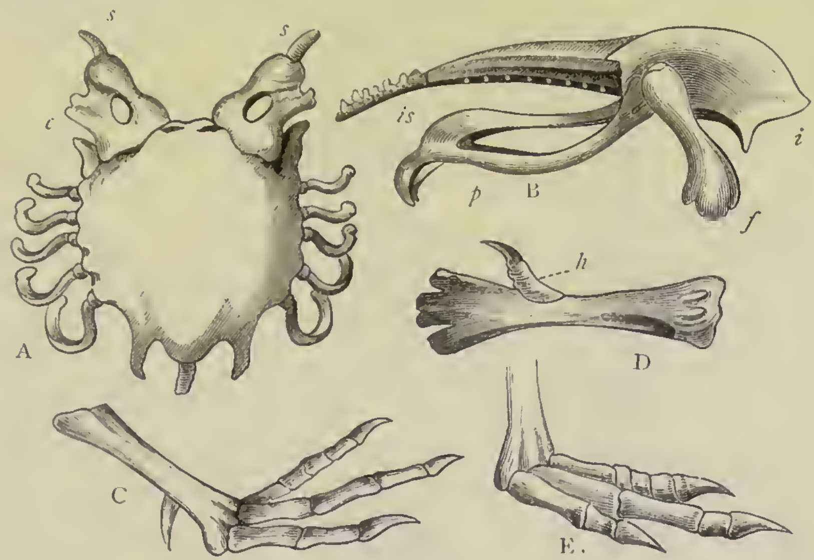

Fig. 411.—Morphology of Ratite Birds. A, Sternum of the Ostrich (*Struthio camelus*): *s* Scapula; *c* Coracoid. B, Side view of the pelvis of the Ostrich: *i* Ilium; *p* Pubis; *is* Ischium; *f* Femur. C, Foot of *Apteryx australis*. D, Tarso-metatarsus of the *Apteryx*, showing the hallux placed high up on its posterior surface. E, Foot of the *Rhea americana*.

the hallux is absent. The order includes the following groups:—

1. *Struthionidæ*.—This group is represented only by the African Ostrich, in which the foot is two-toed, the humerus is long, the hand has two digits, and the pubes unite (as in no other living Bird) to form a ventral symphysis.

The African Ostrich (*Struthio camelus*) occurs in the desert plains of Africa and Arabia, and is the largest of all living birds, attaining a height of from six to eight feet. The South African Ostrich is often considered as a distinct species, under the name of *S. australis*. The head and neck

are nearly naked, and the quill-feathers of the wings and tail have their barbs wholly disconnected, constituting the ostrich-plumes of commerce. The feathers have no "after-shafts." The legs are extremely strong, and are terminated by two toes only, these consisting respectively of four and five phalanges, showing that it is the hallux and the innermost toe which are wanting. The internal one of the two toes is much the larger, and is clawed; the outer toe is small and clawless. The pubic bones (fig. 411, B) are united in a ventral symphysis, and the wing is furnished with a long humerus. The Ostriches run with extraordinary speed, and can outstrip the fastest horse. They are polygamous, each male consorting with several females, and they generally keep together in larger or smaller flocks. The eggs are of great size, averaging three pounds each in weight; and the hens lay their eggs in the same nest, this being nothing more than a hole scratched in the sand. The eggs appear to be hatched mainly by the exertions of both parents, relieving each other in the task of incubation, but also partly by the heat of the sun.

2. *Rheidæ.*—This group includes the "American Ostriches" (*Rhea*), in which the foot (fig. 411, E) is three-toed, the humerus is long, there are two digits in the hand, and the pubes do not meet, while the ischia are joined in a dorsal symphysis above the sacrum. Three species of *Rhea* are known, ranging from Patagonia to Peru, but each inhabiting its own specific area.

3. *Casuariidæ.*—This group includes the Cassowaries and Emeus, in which the foot is three-toed, the humerus is very short, and the hand has only a single digit. The wing-feathers are represented by naked quills instead of by soft plumes, and the feathers have an "after-shaft" almost as long as themselves.

The Cassowaries (*Casuarius*) are represented by several species which inhabit New Guinea and the adjacent islands, and also North Australia, about nine species in all having been recorded. The head of the Cassowaries is furnished with a horny crest, and in several species the neck is provided with naked pendent wattles. The Cassowaries are birds of very large size, and both sexes participate in sitting upon the eggs.

The Emeus (*Dromaius*) are also of large size, but the head and neck are feathered, and there is no horny crest upon the head. Only two species are known (viz., *Dromaius Novæ-Hollandiæ* and *D. irroratus*), both being Australian, but the latter being confined to Western Australia.

4. *Dinornithidæ.*—This group includes a number of gigantic extinct Birds, the remains of which have been found in Post-Tertiary deposits in New Zealand. The principal genus is *Dinornis* itself, in which the foot is three-toed, the hallux being wanting (fig. 412). The feathers are furnished with an "after-shaft." The wings were exceedingly rudimentary, and in some cases the fore-limbs appear to have been wholly absent. The largest species is the *Dinornis giganteus*, one of the most gigantic of living or fossil Birds, the tibia measuring a yard in length, and the total height being at least ten feet. Another species, the *Dinornis elephantopus* (fig. 412), though not standing more than about six feet in height, was of an even more ponderous construction—"the framework of the skeleton being the most massive of any in the whole class of Birds," whilst "the toe-bones almost rival those of the Elephant" (Owen). There is every reason to believe that the *Dinornithidæ* were represented by living species up to quite a recent date, and that it was by human agency that they were exterminated. Not only are the bones very numerous in certain localities, but they are found in the most recent and superficial deposits, and they still contain a considerable proportion of animal matter; whilst in some instances bones have been found with the feathers attached, or with the horny skin of the

legs still adhering to them.[1] Charred bones have been found in connection with native "ovens"; and the traditions of the Maories contain circumstantial accounts of gigantic wingless Birds, the "Moas," which were hunted both for their flesh and their plumage.

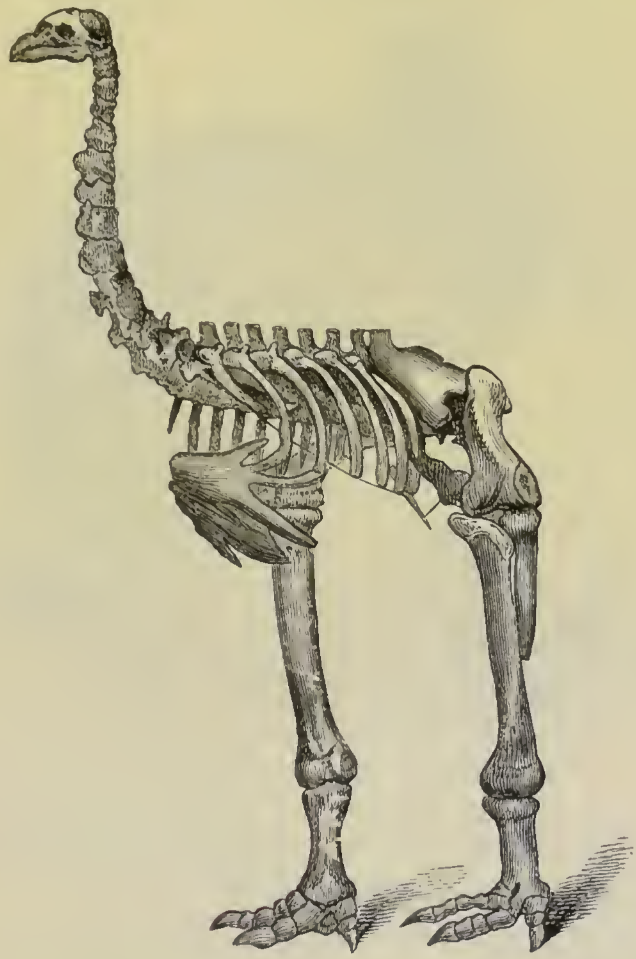

Fig. 412.—Skeleton of *Dinornis elephantopus*, greatly reduced. Post-Pliocene. New Zealand. (After Owen.)

ORDER II. APTERYGES.—This order includes Ratite Birds in which the foot is four-toed, a rudimentary hallux being present. The only living types of this order belong to the genus *Apteryx*, but we may include here the extinct genus *Palapteryx* and its allies, and the less perfectly known genus *Æpyornis*.

1. *Apterygidæ*.—The legs in *Apteryx* are comparatively short, the foot furnished with three toes in front and a short clawed hallux placed on the back of the tarso-metatarsus (fig. 411, C and D). The beak is long, slender, and slightly curved, the tip being obtuse, and the nostrils placed at the

extremity of the upper mandible (fig. 413). The wings are rudimentary, the clavicles being rudimentary, the humerus short, and there being only a single ungual phalanx terminated by a sharp claw. The feathers are long, narrow, and hair-like, and the tail is short and inconspicuous. The four known species of *Apteryx* are confined to New Zealand, the name of

Fig. 413.—*Apteryx australis*, New Zealand.

"Kiwi" being given to them by the natives. They are of comparatively small size as compared with the other Ratite Birds, and are nocturnal in their habits, feeding upon insects and worms.

2. *Palapterygidæ.*—This group comprises certain gigantic extinct Ratite Birds which are found in the Post-Tertiary deposits of New Zealand. They resemble *Dinornis* in many respects, but agree with the recent *Apteryx* in having the hallux developed. The principal genus is *Palapteryx*.

3. *Æpyornithidæ.*—This group includes only a single Ratite bird which inhabited Madagascar in Post-Tertiary times, and the structure of which is still imperfectly known. The only known species is the *Æpyornis maximus*, the eggs of which are eight times the bulk of those of the Ostrich.

CHAPTER LXI.

DIVISIONS OF AVES (*Continued*).

CARINATÆ.

SUB-CLASS IV. CARINATÆ.—The sub-class of the Carinate Birds includes all living birds with the exception of the small sub-class of the *Ratitæ*, and is characterised by the fact that the sternum is furnished with a more or less prominent keel or "carina," the metacarpals are united with one another, the jaws are destitute of teeth, and the quill-feathers have their barbs united by interlocking barbules.

The *Carinatæ* may be divided into fourteen "orders," the characters of which will be briefly considered in what follows. It is to be remembered, however, that only in some cases can the so-called "orders" of Carinate Birds be regarded as equivalent in value to the divisions which bear this name among other groups of animals. The subjoined table shows the general correspondence between the orders here adopted and the six old orders of Carinate Birds which have been in general use:—

I. NATATORES = *Impennes*, *Pygopodes*, *Gaviæ*, *Steganopodes*, and *Chenomorphæ*.
II. GRALLATORES = *Herodii* and *Grallæ*.
III. RASORES = *Gallinæ*, *Columbæ*, and *Crypturi*.
IV. SCANSORES = *Psittaci* and *Picariæ* (in part).
V. INSESSORES = *Passeres* and *Picariæ* (in part).
VI. RAPTORES or ACCIPITRES = *Raptores*.

ORDER I. CRYPTURI.—This order includes only the family of the "Tinamous" (*Tinamidæ*), comprising certain grouse-like birds, in which the tail is exceedingly short or absent.

In general appearance, the Tinamous resemble the ordinary Game-birds, but in various characters connected with the structure of the skull they approach the Ratite Birds. Many of the sutures of the skull are persistent, and the brain is very small. The bill is long and straight, often hooked at its tip, and the foot has a short hallux developed on its hinder aspect, and not touching the ground. The Tinamous are exclusively neotropical, ranging from Patagonia to Mexico, and are essentially terrestrial in their habits.

ORDER II. IMPENNES.—This order includes only the Penguins (*Spheniscidæ*), distinguished by their boat-shaped body, backwardly-placed hind-limbs, and fin-like wings (fig. 414).

The Penguins are entirely adapted for an aquatic life, to which end the hind-limbs are placed at the hinder end of the body, and the three anterior toes are webbed, or united by the skin. The hallux is rudimentary, and the wings are useless as organs of flight, being fin-like and without quill-feathers. They are covered with small scale-like feathers, and are employed by the bird as fins, enabling it to swim under water with great

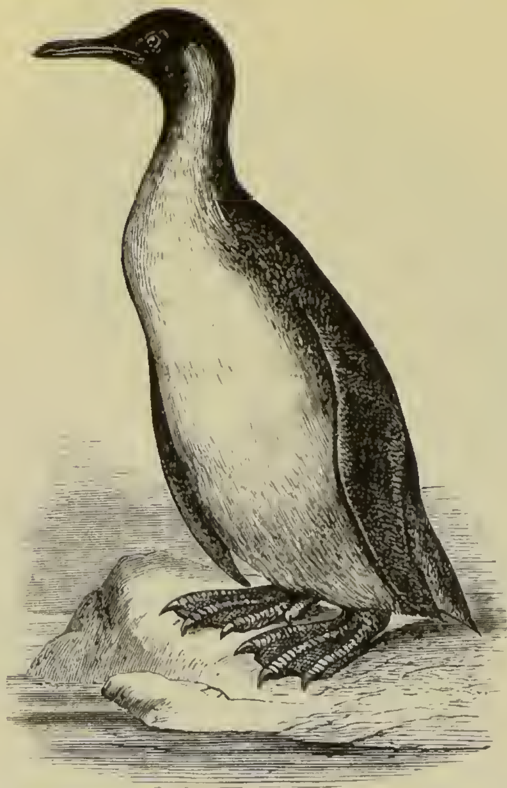

Fig. 414.—Penguin (*Aptenodytes patagonica*).

facility, while they can be used, on necessity, as fore-limbs on land. The neck is short, the centra of the cervical vertebræ having mostly spheroidal faces; the sternum has a keel; and the beak is compressed. When on land, the Penguins stand bolt upright, and in this position they incubate the single egg which they lay. They can also carry the egg about with them, buried among the feathers between the hind-limbs. The Penguins are essentially confined to the Southern Seas, two species being found on the coast of Peru and the Galapagos. Well-known forms are the King-penguin (*Aptenodytes patagonica*, fig. 414) of Patagonia and the Falkland Islands, and the Black-footed Penguin (*Spheniscus demersus*) of the Cape of Good Hope and the seas round Cape Horn.

ORDER III. PYGOPODES.—This order includes the Guillemots, Auks, Grebes, and Divers, and is characterised by the adaptation of the animal to an aquatic life, the body being boat-shaped, with a thick and lustrous plumage, the webbed feet being placed far back, and the wings being provided with

quill-feathers, but being comparatively short, and in some cases (Great Auk) rudimentary. Together with the Penguins, the birds of this order constitute the "Brevipennate" section of the old order *Natatores*.

The Guillemots (*Uria*) are characterised by their short tails, narrow and pointed wings, and completely webbed feet, the hallux being wanting. They are confined to the colder seas of the northern hemisphere, and well-known species are the common Guillemot (*Uria troile*) and the Black Guillemot (*U. grylle*).

The Auks (*Alcidæ*) have the wings short or rudimentary, the three anterior toes webbed, and the hallux wanting. Well-known types belonging to this family are the Razor-bill (*Alca torda*) of the North Atlantic, the Little Auk (*Mergulus alle*) of northern seas, and the common Puffins (*Mormon fratercula*). The Great Auk or Gare-fowl (*Alca impennis*) is remarkable as being one of those birds which appear to have become extinct within the human period, having, in fact, been destroyed chiefly through the agency of man himself. At one time this fine bird was by no means uncommon on both the American and European sides of the North Atlantic, occasionally visiting the coasts of Scotland and Ireland, but the species seems to have been completely exterminated before the middle of this century.

The Divers (*Colymbidæ*) have the three anterior toes completely webbed, and have a free hallux, the neck being tolerably long, and the beak strong. They are found both on the coasts of the sea and in inland waters, and are confined to Arctic and north temperate regions. Familiar species are the Northern Diver or Loon (*Colymbus glacialis*), the Red-throated Diver (*C. septentrionalis*), and the Black-throated Diver (*C. arcticus*).

The Grebes (*Podicipitidæ*) are closely allied to the Divers, but the web between the anterior toes is deeply incised, each toe thus having a separate web. The Grebes have an almost universal distribution, and frequent fresh waters, swimming and diving with the utmost facility. The best-known British species is the Little Grebe or Dabchick (*Podiceps minor*).

ORDER IV. GAVIÆ.—This order corresponds with the "Longipennate" section of the old order *Natatores*, and comprises the Gulls, Terns, and Petrels. The order is characterised by the long and well developed wings, the pointed, sometimes knife-like, sometimes hooked bill, and the fact that the three anterior toes are united by a web, the hallux being present, but being free. The following are the more important groups included in this order :—

1. *Laridæ*, or Gulls and Terns, having powerful wings, a free hinder toe, and the three anterior toes united by a membrane. The Gulls form an exceedingly large and widely distributed group of birds; and the Terns or Sea-swallows are equally beautiful, if not quite so common. The Terns are distinguished by their long and pointed wings, forked tail, and comparatively short legs. They fly with great rapidity over the surface of the sea, from which they pick up their food.

2. *Procellaridæ*, or Petrels, closely resembling the true Gulls, but having a rudimentary hinder toe, and having the upper mandible strongly hooked. The smaller species of Petrel are well known to all sailors under

the name of Storm-birds and Mother Carey's Chickens. They are nocturnal or crepuscular in their habits, breed in holes in the rocks, lay but one egg, and are almost all of small size and more or less sombre plumage. The largest member of the group is the gigantic Albatross (*Diomedea exulans*), not uncommonly found far from land in the tropical seas of both the north and south hemispheres. The Albatross sometimes measures as much as fifteen feet from the tip of one wing to that of the other, and the flight is powerful in proportion.

ORDER V. STEGANOPODES (*Totipalmatæ*).—This order comprises the Frigate-birds, Pelicans, Cormorants, Gannets, and Darters, and corresponds with the "Totipalmate" section of the old order *Natatores*. The distinguishing character of the order is that the hind-toe (hallux) is directed more or less towards the front, and is united with the innermost of the three

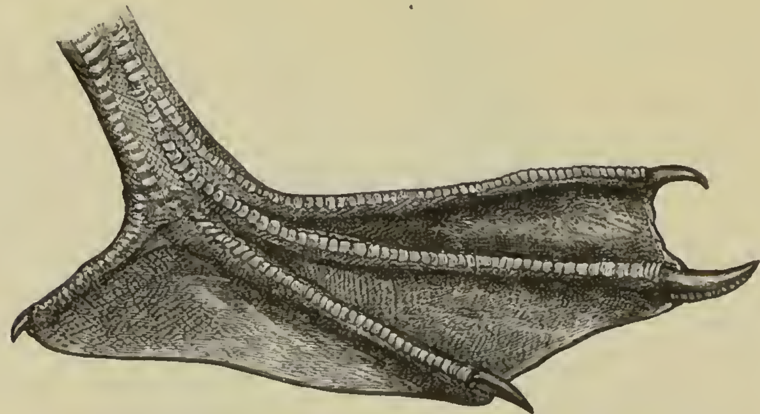

Fig. 415.—"Totipalmate" foot of the Gannet (*Sula bassana*).

anterior toes by a membrane, all the four toes being thus included in the web. The wings are well developed, and some of the members of this order are birds of remarkably powerful and sustained flight.

The Pelicans (*Pelicanidæ*) are large birds, which subsist on fish, and are found in Europe, Asia, Africa, and the New World. They sometimes measure as much as from ten to fifteen feet between the tips of the wings, and most of the bones are pneumatic, so that the skeleton is extremely light. The lower mandible is composed of two flexible branches which serve for the support of a large "gular" pouch, formed by the loose unfeathered skin of the neck. The fish captured by the bird are temporarily deposited in this pouch, and the parent birds feed their young out of it. The bill is long and straight, and the upper mandible is strongly hooked at the tip.

In the Cormorants (*Phalacrocorax*) there is no pouch beneath the lower mandible, but the skin of the throat is very lax and distensible; the nail of the middle toe is serrated. They are widely distributed over the world, the "Shag" (*P. graculus*) and the common Cormorant (*P. carbo*) being familiar species. The Gannets (*Sula*) have a compressed bill, the margins

of which are finely crenate or toothed. They occur abundantly on many parts of the coasts of northern Europe, one of the most noted of their stations being the Bass Rock at the mouth of the Firth of Forth. The species here is the well-known "Solan Goose" (*Sula bassana*). Another species (*Sula variegata*) is of greater importance to man, as being one of the birds from the accumulated droppings of which guano is derived. The Frigate-birds (*Tachypetes*) are chiefly remarkable for their extraordinary powers of flight, conditioned by their enormously long and powerful wings and long forked tail. They occur on the coasts of tropical America, and are often found at immense distances from any land. The Tropic-birds (*Phaeton*) inhabit intertropical regions, and are found far out at sea. They have short feeble feet, and long pointed wings.

The Darters or Snake-birds (*Plotus*) are somewhat aberrant members of this group, characterised by their elongated necks and long pointed bills. They occur in America, Africa, and Australia, and catch fish by suddenly darting upon them from above.

ORDER VI. CHENOMORPHÆ (*Anseres*).—This order comprises the "Lamellirostral" section of the old order *Natatores* (viz., Ducks, Geese, Swans, and Flamingoes), together with the aberrant group of the "Screamers" (*Palamedeidæ*). In the most typical members of this order, the beak (fig. 416) is flat-

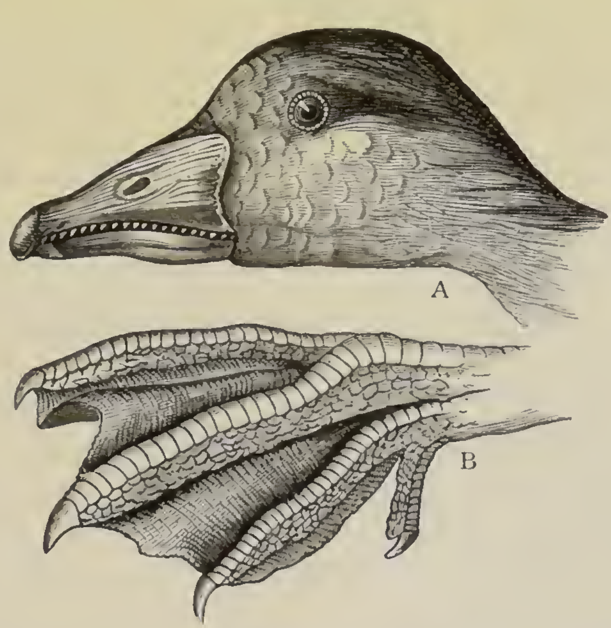

Fig. 416.—A, Head of the Grey Lag Goose; B, Foot of the domestic Goose.

tened in form, and covered with a soft skin. The edges of the bill are further furnished with a series of transverse plates or lamellæ, which form a kind of fringe or "strainer," by means of which these birds sift the mud in which they habitually seek their food. The bill is richly supplied with fila-

ments of the fifth nerve, and doubtless serves as an efficient organ of touch. The feet are furnished with four toes, of which three are turned forwards, and are webbed, whilst the fourth is turned backwards, and is free. The trachea in the males is often enlarged or twisted in its lower part, and co-operates in the production of the peculiar clanging note of most of these birds. The body is heavy, and the wings only moderately developed.

The Ducks (*Anatidæ*) have the hallux fringed with a narrow membranous lobe, which is of considerable width in the Sea-ducks. The Ducks have an almost universal distribution, well-known forms being the Wild Duck or Mallard (*Anas boschas*), the Teal (*Querquedula crecca*), the Widgeon (*Mareca penelope*), the Shovellers (*Spatula*), the Scaup-duck, Canvas-back, and Pochard (*Fuligula*), the Sheldrakes (*Tadorna*), the Scoter-ducks (*Œdemia*), the Mergansers (*Mergus*), and the Eider-ducks (*Somateria*).

The *Anseridæ* are distinguished from the Ducks chiefly by their stronger and longer legs, and comparatively shorter wings. Good examples are the Grey Lag (*Anser ferus*), the Canada Goose (*A. canadensis*), the Bean-goose (*A. segetum*), and the Snow-goose (*A. hyperboreus*). All the domesticated varieties of Geese appear to be undoubtedly descended from the "Grey Lag" Goose, a common wild species which is found in marshy districts in Europe generally, in Northern Africa, and as far east as Persia.

In the Swans the neck is extremely long, and the legs are short. In the Hooper Swan (*Cygnus ferus*) the sternal keel is double, and forms a cavity for the reception of a convoluted portion of the trachea. This is not the case, however, with the Mute or Common Swan (*C. olor*), the Black Swan (*C. atratus*), or the Trumpeter Swan (*C. buccinator*), all well-known members of the group.

The family *Palamedeidæ* includes certain South American birds, which have affinities to the *Grallæ* and the Gallinaceous birds. The common "Screamer" (*Palamedea cornuta*) has long legs, and the toes incompletely webbed. It has a cylindrical horn-like process on the head, and horny spurs implanted on the edge of the wing.

The Flamingoes (*Phœnicopteridæ*) are intermediate in their characters between the Geese and the Herons and Storks. They resemble the former in the fact that the bill is lamellate, and also in having the feet completely palmate; but they approach the latter in the great length of the legs. The bill is singularly bent, both mandibles being suddenly curved downwards from the middle. The common Flamingo (*Phœnicopterus antiquorum*) inhabits Africa and Southern Europe. The Ruddy Flamingo (*P. ruber*) is South American, as are other species.

ORDER VII. HERODII.—This order includes the Herons, Storks, Ibises, and Spoonbills, and is characterised by the possession of a long "cultirostral" bill, which usually exceeds the head in length, and is compressed from side to side. The nostrils are placed high up on the beak, and there is no "cere." The legs are long, and unfeathered in their lower part, and the toes are four in number, elongated, and usually

partially united towards their bases by membrane, but never properly "webbed."

The Herons (*Ardeidæ*) have a large hallux, the three anterior toes being long and slender, and the inner edge of the middle toe being pectinated or comb-like. An excellent example of this widely distributed family is the common Grey or Crested Heron (*Ardea cinerea*) of Britain. The Herons

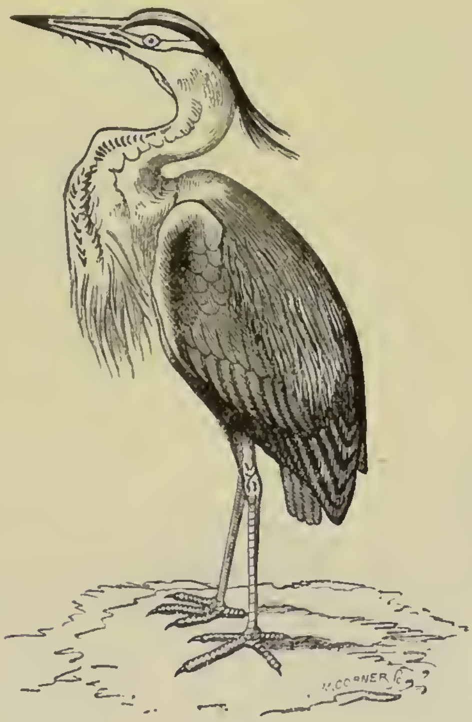

Fig. 417.—Crested Heron (*Ardea cinerea*). Europe.

wade about in the shallow waters of lakes, rivers, or the sea-shore, and live principally upon fish. Allied to the typical Herons are the Night Herons (*Nycticorax*), the Bitterns (*Botaurus*), and the Boat-bills (*Cancroma*).

The Storks (*Ciconiidæ*) have the beak thick, the toes shorter than in the Herons, and the middle toe free from serrations. The common Stork (*Ciconia alba*) is rarely found in Britain, but occurs not uncommonly on the continent of Europe. It frequents marshes, and feeds on frogs, fishes, and other aquatic animals. In the allied genus *Leptoptilus*, including the great Storks known as the Marabou (*L. crumeniformis*) of Africa, and the Adjutant (*L. argala*) of India, there is attached to the throat a singular naked sac, which has, however, no connection with the gullet of the bird. A related genus is *Mycteria*, represented by species in Africa, India, and Australia, but most familiarly known in the person of the Jabiru (*M. americana*) of the neotropical region. Also related to the Storks are the Wood-ibises (*Tantalus*), species of which abound in the hot regions of both the Old and New World.

The Spoonbills (*Plataleidæ*) are very like the Storks in general form and habits, but the bill is flattened out towards the end so as to form a

broad spoon-like plate. The common White Spoonbill (*Platalea leucorodia*) is commonly found on the continent of Europe, but is of very rare occurrence in Britain. Related to the Spoonbills are the true Ibises, in which the beak is long, slender, and arcuate. The Ibises are found in almost all warm countries, some of them being of very beautiful colours. The most famous species is the Sacred Ibis (*Ibis æthiopica* or *I. religiosa*) of Africa, which was worshipped by the ancient Egyptians, and commonly represented on their monuments.

ORDER VIII. GRALLÆ.—This order comprises the greater number of the birds formerly included in the order of the *Grallatores* or "Waders." The *Grallæ*, for the most part, frequent the banks of rivers and lakes, the shores of estuaries, marshes, lagoons, and shallow pools, though some of them keep almost exclusively to dry land, preferring, however, moist and damp situations. In accordance with their semi-aquatic, amphibious habits, most of the *Grallæ* have long legs, though some of the more strictly terrestrial types (such as the Rails) have the legs comparatively short. In all, the tarso-metatarsus, and at any rate a portion of the lower end of the tibia, is unfeathered (fig. 418). The toes are long and slender, and

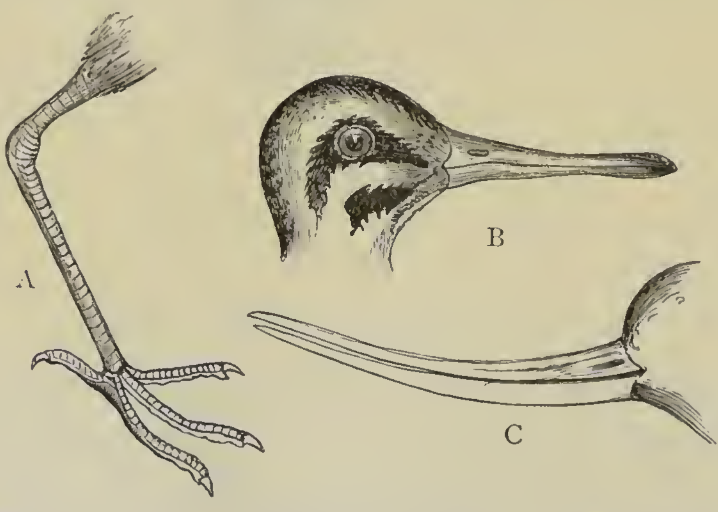

Fig. 418.—Grallæ. A, Leg and foot of the Curlew; B, Head of Snipe; C, Beak of the Avocet.

mostly free, though in some cases (Coots) they have lateral fringes, thus becoming semi-palmate. The wings are usually long, and the power of flight is generally considerable. The nostrils are large, and are placed comparatively low down, and the beak is often long, though sometimes of no great length and compressed. Many of the *Grallæ* breed in cold countries. and migrate at the approach of winter to warmer regions. The young are always "precocious," being covered with down,

and capable of taking care of themselves as soon as hatched. The following are the principal groups included in the *Grallæ* :—

1. *Rallidæ.*—This family comprises the Water-hens, Coots, &c., and is characterised by having the foot with four elongated, sometimes lobate, toes, while the wings are of moderate or less than average size. In many of their characters a considerable number of the birds of this family approach the Rasorial birds, and differ from the true Waders. The beak is mostly short, rarely longer than the head, and is compressed from side to side, or wedge-shaped. The legs are strong and not particularly lengthy ; but the toes are often of great length, and are furnished with long claws. The neck is not very long, and the tail is very short. Some of them are strictly aquatic in their habits, and, like the Coots, approach in many respects to the typical Swimmers ; others, again, are exclusively terrestrial. Among the most familiar members of this group are the Water-hens or Gallinules, represented in this country by the common Moor-hen (*Gallinula chloropus*). Though the Water-hens are aquatic in their habits, their toes are not fringed. On the other hand, in the Coots (*Fulica*), the foot is semipalmate, the toes being bordered with membranous lobes (fig. 419). The common British species is the *Fulica atra ;* but the Coots have an almost universal distribution. The typical Rails have the toes moderately long, with short claws. Some of them, like the common Water-rail (*Rallus aquaticus*), frequent marshy localities, and swim and dive readily. Others, like the Corn-crake (*Crex pratensis*) are essentially terrestrial in their habits. Familiar North American Rails are the Marsh-hen (*Rallus elegans*) and the Virginian Rail (*R. virginianus*). The Jacanas differ from the typical Rails in the possession of extremely long and slender toes, furnished with long claws, enabling the bird to run about on the leaves of aquatic plants. The typical Jacanas (*Parra*) are South American ; but allied forms occur in Southern Asia.

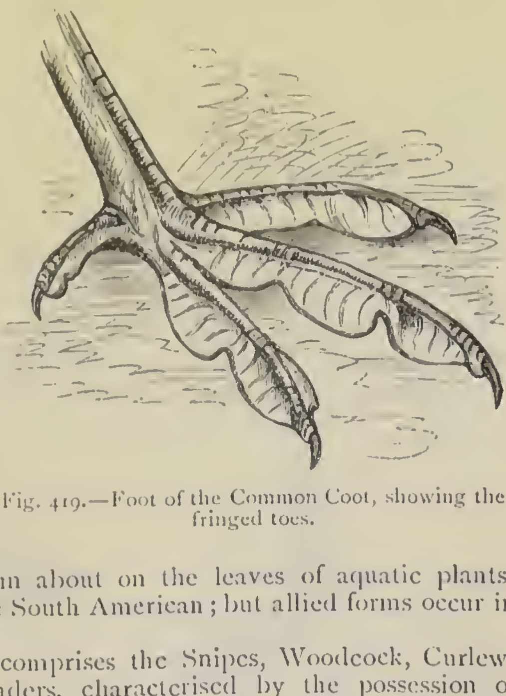

Fig. 419.—Foot of the Common Coot, showing the fringed toes.

2. *Scolopacidæ.*—This group comprises the Snipes, Woodcock, Curlew, and other "longirostral" Waders, characterised by the possession of long, slender, soft bills, grooved for the perforations of the nostrils (fig. 418, B). The legs are sometimes rather short, sometimes of great length ; the toes are of moderate length, and the hallux is usually short, and is sometimes absent. The bill in these birds serves as an organ of touch, being used as a kind of probe to feel for food in mud or marshy soil. To fulfil this purpose, the tip of the bill is furnished with numerous filaments of the fifth nerve. They feed mostly upon insects and worms, and are not strictly aquatic in their habits, mostly frequenting marshy

districts, moors, fens, the banks of rivers or lakes, or the shores of the sea.

In this family of the Long-billed Waders are the various species of Snipe (*Gallinago*) and Woodcock (*Scolopax*), the Sandpipers (*Tringa*), the Curlews (*Numenius*), the Turnstones (*Strepsilas*), the Ruffs (*Machetes*), the Redshanks (*Totanus*), the Godwits (*Limosa*), and others which need no special notice.

3. *Charadriidæ.*—This family includes the Plovers and their allies, and is characterised by the fact that the legs are long and slender, the toes are united at their bases by a small membrane, and the hind-toe is very small and raised above the ground. In this group are the true Plovers and Lapwings (*Charadrius*, *Vanellus*, &c.), the Pratincoles (*Glareola*), the Longshanks (*Himantopus*), and the Oyster-catcher (*Hæmatopus*).

4. *Otididæ.*—This family includes the Thick-knee (*Œdicnemus*), the Coursers (*Cursorius*), and the Bustards (*Otis*), and forms a transition between the typical *Grallæ* and the Game-birds (*Gallinæ*). The members of this family have long legs, well adapted for running, the toes being short, with stout claws, and the hallux being absent. The wings are moderately developed, and the tail is of considerable size. The Bustards (*Otis*) are found over the greater part of the Old World, and the Great Bustard (*O. tarda*) was at one time not uncommon in Britain.

5. *Gruidæ.*—The Cranes have long beaks, and very long legs, unfeathered from the middle of the tibia downwards. The toes are slender, and the hallux is raised off the ground. The tail is short, but the wings are long, and many of the *Gruidæ* perform long migrations. The typical Cranes (*Grus*) have an almost universal distribution, the common European species being the *Grus cinerea.* The Crowned Cranes (*Balearica*) are exclusively African, and the Demoiselle Cranes (*Anthropoides*) inhabit Europe, Africa, and India.

ORDER IX. GALLINÆ.—This division comprises the Game-birds, the typical members of the old order *Rasores.* The "Gallinaceous Birds" are characterised by the convex, vaulted upper mandible, having the wide nostrils pierced in a membranous space at its base. The legs are strong and robust, mostly covered with feathers as far as the joint between the

Fig. 420.—Rasores. A, Foot of Fowl (*Gallus Bankiva*); B, Head of Guinea-fowl.

tibia and the tarso-metatarsus. There are four toes—three in front and one behind—the latter (hallux) being short, and placed at a higher level than the other toes (fig. 420, A). All the toes are furnished with strong blunt claws suitable for

scratching in the soil. The food of the *Gallinæ* consists chiefly of hard grains and seeds, and, in accordance with this, they have a capacious crop and an extremely strong and muscular gizzard. The body is usually heavy, and the wings comparatively short and weak, the flight being feeble, and accompanied with a whirring sound. The back of the tarso-metatarsus is often furnished in the males (in the females also in the Java Peacock) with a spur (*calcar*), which is used as an offensive weapon. In *Polyplectron* the leg of the male has two or three of these spurs. Most of the *Gallinæ* are polygamous, but some forms (Guinea-fowl, Red Grouse, Partridge, &c.) are monogamous. In accordance with their generally polygamous habit, the males are usually more brilliantly coloured than the females. They mostly nidificate, or build their nests, upon the ground. The males take no part in either nidification or incubation, and the young are "precocious," being able to run about and obtain food for themselves from the moment they quit the egg. The following are the principal groups included in the *Gallinæ*:—

1. *Tetraonidæ*.—In the Grouse family the nostrils are covered by a scale or by feathered skin. The legs, and often the toes, are feathered (fig. 421, A), and there are no spurs. Good examples of this family are the European types, the Capercailzie (*Tetrao urogallus*), the Black-cock (*T. tetrix*), the Red Grouse (*Lagopus scoticus*), and the Ptarmigan (*L. mutus*). Of the many American Grouse, the three most characteristic types are perhaps the Prairie-hen (*Cupidonia cupido*), the Cock of the Plains (*Centrocercus urophasianus*), and the Ruffed Grouse (*Bonasa umbellus*).

2. *Perdicidæ*.—This group includes the Partridges and their allies, distinguished from the Grouse by their unfeathered open nostrils, and bare scaly tarso-metatarsus. Familiar European species of Partridge are the common Partridge (*Perdix cinerea*) and the Red-legged Partridge (*P. rufa*). Besides the typical Partridges, this family includes the Francolins (*Francolinus*) and the Quails (*Coturnix*). The "American Partridges" are sometimes separated as a distinct family (*Odontophoridæ*). Good examples are the Virginia Partridge or "Quail" (*Ortyx virginianus*) and the Plumed Quails (*Lophortyx*).

3. *Phasianidæ*.—In the Pheasant family, there are commonly naked spaces of skin on the head or cheeks, and also often combs or wattles. The males carry spurs on the tarso-metatarsus. The typical Pheasants (*Phasianus*) are all confined to the Old World, and are essentially Asiatic. The common Pheasant (*P. colchicus*) has, however, become naturalised in Europe. The Pea-fowl (*Pavoninæ*) are entirely Asiatic in their natural range; and every one is familiar with the common Pea-fowl (*Pavo cristatus*), the beautiful "tail" of the males being formed by the great elongation of the tail-coverts. The Fowls (*Gallus*) are exclusively confined to southern Asia and the Indian Archipelago. One of the Jungle-fowl of India (*Gallus Bankiva*) is supposed to be the principal wild form from which the common domestic Fowls have descended. The Turkeys (*Meleagris*) are natives of North America, Mexico, and Central America, only three species being known. The domestic Turkey has

descended from the common Turkey (*M. gallopavo*). Lastly, the Guinea-fowls (*Numida*) are exclusively found in Africa and Madagascar, the common domesticated Guinea-fowl being the *Numida meleagris.*

4. *Pteroclidæ.*—The "Sand-grouse" included in this family are confined to the Old World, being principally African and Asiatic. They have long and pointed wings, thus approaching somewhat to the Pigeons.

5. *Turnicidæ.*—The "Bush-quails" included in this group are of small size, and make an approach to the Plovers. They are unlike the *Gallinæ* generally in the absence of the hallux. They are natives of Europe, Africa, Asia, and Australia.

6. *Megapodidæ.*—The "Mound-birds" forming this family inhabit Australia, most of the Pacific islands, and India, and have large feet, the toes of which end in long claws. They bury their eggs in the sand, or lay them in mounds of vegetable rubbish which they scrape together, the eggs being hatched either by the warmth of the sun, or by the heat evolved by the fermentation of the accumulated vegetable matter.

7. *Cracidæ.*—The "Curassows" included in this family belong to Central and Southern America, and differ from the *Gallinæ* in general in being, to a large extent, arboreal in habit. They have long legs, and the hind-toe is placed on the same plane as the anterior toes. They are large and handsome birds, and are often domesticated. A well-known form is the "Crested Curassow" (*Crax alector*) of Mexico and Central America.

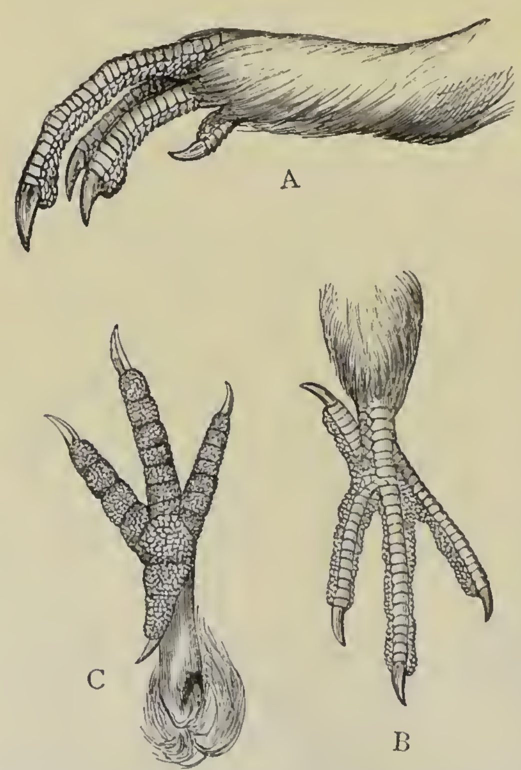

Fig. 421.—A, Foot of Black-cock (*Tetrao tetrix*). B and C, Upper and under views of the foot of the Wood-pigeon (*Columba palumbus*).

Order X. Columbæ.—This order comprises the Pigeons and Doves, which have often been included with the preceding in the single order *Rasores*, under the name of *Columbacei*. The Pigeons are, in fact, closely related to the *Gallinæ*, this being seen particularly in the form of the bill, the upper mandible being convex in front, and having the base covered with bare or fleshy skin. They differ from the *Gallinæ*, however, in having the wings long and pointed, and in being thus endowed with considerable powers of flight. In place, therefore, of being principally ground-birds, they are to a great extent arboreal in their habits,

and in accordance with this the feet are slender, and are well adapted for perching (fig. 421, B and C). There are four toes, three in front and one behind, and the former are never united towards their bases by a membrane, though the base of the outer toe is sometimes united to that of the middle toe. The hallux is articulated on the same plane as the other toes, and touches the ground in walking. A still more fundamental difference between the *Columbæ* and the *Gallinæ*, is found in the fact that the young of the former are always born in an unfeathered and helpless condition, and thus require to be nursed and fed by the parents for a longer or shorter time after they are hatched. All the *Columbæ*, lastly, are monogamous, and pair for life; and the males, in accordance with this, are devoid of spurs or other weapons of offence. The following groups are included in this order:—

Fig. 422.—Columbidæ. Rock-pigeon (*Columba livia*).

1. *Columbidæ.*—This family includes the typical Pigeons and Doves, of which about four hundred species are known, with an almost universal distribution. They are essentially tree-inhabiting forms, with a short tarso-metatarsus, and slender toes adapted for perching. The innumerable varieties of the domestic Pigeons have all descended from the Rock-pigeon (*Columba livia*, fig. 422), which is a native of the countries surrounding

the Mediterranean. Other familiar species are the Wood-pigeon (*Columba palumbus*), the Stock-dove (*Columba œnas*), the Turtle-dove (*Turtur auritus*), and the Passenger-pigeon (*Ectopistes migratorius*) of North America. The "Fruit-pigeons" (*Carpophaga* and *Treron*) are mostly green in colour, often very beautifully marked, and are principally inhabitants of Australia, the Malayan Archipelago, and Southern Asia, species of *Treron* also occurring in the Ethiopian region.

2. *Gouridæ.*—The "Crowned-pigeons" or "Ground-pigeons" included in this family are natives of New Guinea and adjacent islands. They are ground-loving birds, and therefore make an approach to the *Gallinæ.*

3. *Didunculidæ.*—This family includes only the singular little *Didunculus strigirostris* of the Navigator or Samoan group of islands in the Pacific. The wings in *Didunculus* are well developed, and the upper mandible of the beak is strongly arched and hooked towards its tip. Though naturally a ground-loving bird, the *Didunculus* appears of late years to have become largely arboreal in its habits. It has a special interest, as being, in the opinion of many ornithologists, related to the extinct Dodo.

Fig. 423.—Skeleton of the Dodo (*Didus ineptus*), restored. (After Owen.)

4. *Dididæ.*—This group is represented only by the Dodo and the Solitaire, two great, non-flying Pigeons, both of which have become exterminated within the last two centuries. The Dodo (*Didus ineptus*, fig. 423) formerly inhabited the island of Mauritius in great numbers, but the last

record of its occurrence dates from the latter part of the seventeenth century. It was a large and heavy bird, bigger than a swan, and entirely unlike the Pigeons in general appearance. The wings were rudimentary, and completely useless as organs of flight. The legs were short and stout, the feet had four toes each, and the tail was extremely short, carrying, as well as the wings, a tuft of soft plumes. The beak (unlike that of any of the *Columbæ* except the little *Didunculus strigirostris*) was strongly arched towards the end, and the upper mandible had a strongly-hooked apex, not at all unlike that of a bird of prey. The Dodo owed its extermination to the fact that it was good to eat, and that it was unable to fly. At present all the known remains of this singular bird that exist are some old, but apparently faithful, oil-paintings, and a few fragmentary remains, to which explorations in the Recent deposits of the island have added a large number of bones. Allied to the Dodo, and, like it, incapable of flight, is the Solitaire (*Pezophaps*) of Rodriguez, a small island lying about 300 miles to the east of Mauritius. The Solitaire appears to have been in existence up to about the middle of the eighteenth century, and a large number of its bones have been obtained in the Recent deposits of Rodriguez. It had longer legs than the Dodo, and its bill was not so strongly arched.

CHAPTER LXII.

SUB-CLASS CARINATÆ—Continued.

Passeres, Picariæ, Psittaci, and Raptores.

Order XI. Passeres or Insessores.—The great order of the Passerine Birds or "Perchers" is principally characterised by the form of the foot, which is adapted for perching. The legs are slender and short, and the foot has three anterior toes and a backwardly-directed hallux, all the toes carrying slender curved claws (fig. 424, E). The claw of the hallux is longer than that of any of the anterior toes, and the two outer toes have their bases united by a very short membrane.

"The *Perchers* form the largest and by far the most numerous order of birds, but are the least easily recognisable by distinctive characters common to the whole group. Their feet, being more especially adapted to the delicate labours of nidification, have neither the webbed structure of those of the *Swimmers*, nor the robust strength and destructive talons which characterise the feet of the *Birds of Rapine*, nor yet the extended toes which enable the *Wader* to walk safely over marshy soils and tread lightly on the floating leaves of aquatic plants; but the toes are slender, flexible, and moderately elongated, with long, pointed, and slightly curved claws.

"The Perchers in general have the females smaller and less brilliantly coloured than the males; they always live in pairs, build in trees, and display the greatest art in the construction of their nests. The young are excluded in a blind and naked

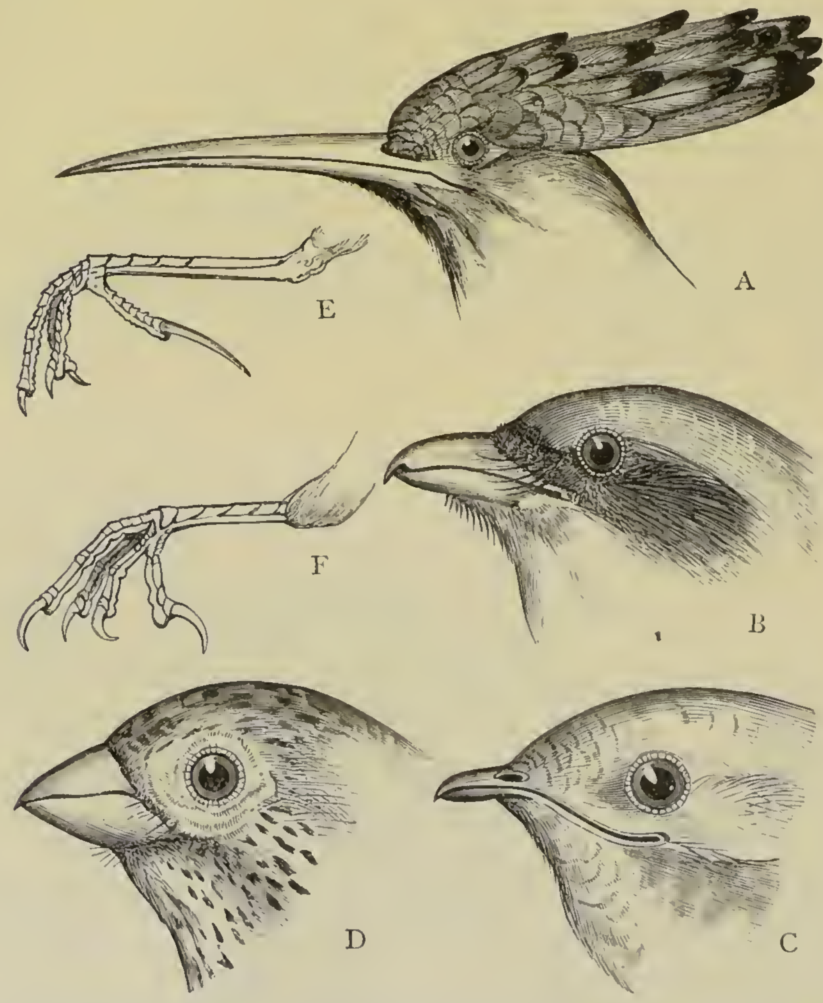

Fig. 424.—Forms of the foot and beak in Passerine and Picarian Birds. A, Head of Hoopoe (*Upupa epops*), showing the tenuirostral type of beak. B, Head of Red-backed Shrike (*Lanius collurio*), showing the dentirostral type of beak. C, Head of White-bellied Swift (*Cypselus melba*), showing the fissirostral type of beak. D, Head of Corn-bunting (*Emberiza miliaria*), showing the conirostral type of beak. E, Foot of the Yellow Wagtail (*Motacilla sulphurea*). F, Foot of a Finch, (*Fringilla*).

state, and are wholly dependent for subsistence during a certain period on parental care. The brain arrives in this order at its greatest proportionate size; the organ of voice here attains its greatest complexity, and all the characteristics of the bird, as power of flight, melody of voice, and beauty of plumage, are

enjoyed in the highest perfection by one or other of the groups of this extensive and varied order."—(Owen.)

The food of the *Passeres* is of a very varied kind, some being exclusively insect-feeders, others living upon seeds and grains, while many are omnivorous, feeding indifferently upon vegetable substances or upon small animals of all kinds. The form of the beak is very varied in the Passerine Birds, but four principal types may be recognised. In the first of these, the beak is what has been generally called "conirostral," being on the whole widely conical, broad at the base, and tapering with considerable rapidity to the apex (fig. 424, D). In the second or "dentirostral" type of bill, the upper mandible has a more or less distinct notch in its lower margin near the tip (fig. 424, B). In the third or so-called "fissirostral" type of bill, the beak is short, with a wide gape, its sides often protected by bristles (fig. 424, C). This form of bill occurs also in some Picarian birds. Lastly, the so-called "tenuirostral" type of bill—likewise seen in various Picarian birds, such as the Hoopoe (fig. 424, A)—is long and slender, gradually tapering from the base to the apex.

The order of the Passerine Birds is an exceedingly large one, and comprises more than half the known species of the class *Aves*. The classification of the order into minor groups has proved a matter of corresponding difficulty, and ornithologists are as yet by no means agreed as to the basis upon which the order should be arranged. Here, therefore, it will be sufficient to glance in the briefest possible manner at the principal families of the order.

The great majority of the *Passeres* are what would usually be called "Song-birds," and all of these have the muscles of the lower larynx or "syrinx" attached to the ends of the bronchial semi-rings (*Passeres acromyodi*). On the other hand, there are a few groups of the order, mostly confined to the New World, which are songless, and have the muscles of the syrinx attached to the middle of the bronchial semi-rings (*Passeres mesomyodi*). The following are the principal families included in the more normal division of *Passeres*, often spoken of as the division of the *Oscines* or Song-birds:—

1. *Corvidæ*.—This is a large group of Passerine birds, characterised by their long, strong, and compressed beak, the base of which is furnished with bristles. The Crow family has representatives in almost every region of the globe, familiar British forms being the Raven (*Corvus corax*), the Carrion Crow (*C. corone*), the Rook (*C. frugilegus*), the Hooded Crow (*C. cornix*), the Jackdaw (*C. monedula*), the Red-legged Crow or Chough (*Fregilus graculus*), the Magpie (*Pica rustica*), and the common Jay (*Garrulus glandarius*).

2. *Paradiseidæ.*—The "Birds of Paradise" comprised in this family are confined to New Guinea and the neighbouring islands, a few forms only (such as the Rifle-birds) being Australian. They differ from the Crows in the proportions of the toes and in the greater slenderness of the beak, and they feed upon fruit and insects. They are remarkable for the brilliant plumage of the males, the females being much less gorgeously feathered. In the words of Mr Wallace—"They are characterised by extraordinary developments of plumage, which are unequalled in any other family of birds. In several species large tufts of delicate, bright-coloured feathers spring from each side of the body, forming trains, fans, or shields; and the middle feathers of the train are often elongated into wires, twisted into fantastic shapes, or adorned with the most brilliant metallic tints. In another set of species, the accessory plumes spring from the head, the back, or the shoulders; whilst the intensity of colour and of metallic lustre displayed by their plumage is not to be equalled by any other birds, except, perhaps, the Humming-birds, and is not surpassed by these."

3. *Oriolidæ.*—The "Orioles" are entirely confined to the Old World, a familiar species being the Golden Oriole (*Oriolus galbula*) of Southern Europe and Africa. [The birds generally called "Orioles" in the United States belong to a different family—viz., the *Icteridæ.*]

4. *Muscicapidæ.*—The "Fly-catchers" feed upon insects, and have a short bill, notched in front, and having its base furnished with bristles. They are mostly sedentary, catching their prey from a fixed point. A familiar example is the common Fly-catcher (*Muscicapa grisola*).

5. *Turdidæ.*—The "Thrushes" have the bill of moderate length, compressed, and curved towards its tip, and are mostly insectivorous. The family is represented in Britain by the familiar Song-thrush (*Turdus musicus*), the Fieldfare (*T. viscivorus*), and the Blackbird (*T. merula*). The widely distributed "Robin" of the United States and Canada is a Thrush (*Turdus migratorius*); and the American Mocking-birds (*Mimus*) also belong to this family.

6. *Sylviidæ.*—This family is very closely related to the preceding, and the boundaries between the two cannot be strictly defined. The beak is awl-shaped, and the tarso-metatarsus is covered with separate shields. Many of the most familiar song-birds belong here. Well-known forms are the true Warblers (*Sylvia*), the Nightingales (*Luscinia*), the Gold-crested Wren (*Regulus*), the Robin Redbreast (*Erythaca rubecula*), the Stonechats (*Saxicola*), the Hedge-sparrows (*Accentor*), and the Redstarts (*Ruticilla*). The true Wrens (*Troglodytes*) are sometimes placed in the present family, but are often regarded as the type of a separate family.

7. *Laniidæ.*—The "Shrikes" or "Butcher-birds" included in this family have the upper mandible (fig. 424, B) hooked at its point, and with a marginal tooth near its tip. They are carnivorous, feeding mostly on worms and insects, but occasionally destroying small birds or mice.

8. *Paridæ.*—The "Titmice" are small, often exceedingly elegant birds, with a conical straight bill, and a well-developed tail. There is no notch in the tip of the upper mandible. The Titmice have a very wide distribution, being particularly abundant in the Palæarctic and Nearctic provinces. Common British species are the Great Titmouse (*Parus major*), and the Blue-headed Titmouse (*P. cæruleus*). Closely allied to the Tits are the Nut-hatches (*Sitta*).

9. *Certhiidæ.*—The "Creepers" are very like Woodpeckers in appearance and habits. The tail-feathers are stiff, and assist the bird in running up the trunks of trees. The bill is long, slender, and curved. The Creepers are insectivorous, the common Brown Creeper (*Certhia familiaris*) being abundant in Britain.

10. *Meliphagidæ.*—The "Honey-eaters" are exclusively confined to the Australian province, and are characterised by their long, curved, slender bills, and by the fact that the long and extensile tongue is cleft, and terminates in a brush of bristle-like filaments.

11. *Nectariniidæ.*—The "Sun-birds" are nearly related to the preceding, having "tenuirostral" beaks, with a protrusible and deeply cleft tongue. They are birds of beautiful plumage, resembling the Humming-birds both in appearance and habits. They are confined to the hotter regions of the Old World, being particularly abundant in Africa and Southern Asia.

12. *Motacillidæ.*—The "Wagtails" have slender bills, generally long tails, and the wings of moderate length, with nine primary quill-feathers. Besides the true Wagtails (*Motacilla*), the family includes the lark-like Pipits (*Anthus*).

13. *Hirundinidæ.*—The true "Swallows" included in this family exhibit the closest resemblance in externals to the Swifts, but nevertheless present wide differences from the latter as regards the details of their internal organisation. They have the "fissirostral" type of beak (fig. 424, C), with the gape wide, and bordered by bristles. The wings are very long, with nine primary quill-feathers, the tail forked, and the legs short and weak, the hallux being turned backwards. The Swallows are insectivorous, and catch their prey upon the wing. The Swallows have an almost universal distribution, common British species being the common Swallow (*Hirundo rustica*), the Martin (*H. urbica*), and the Sand-martin (*H. riparia*).

14. *Tanagridæ.*—The "Tanagers" in many respects resemble the true Finches, but possess a "dentirostral" bill, the upper mandible being notched or toothed. They feed on fruits and insects, and are often brilliantly coloured. They are exclusively confined to the New World, and are mostly South American.

15. *Fringillidæ.*—The great family of the "Finches" is distributed over the whole world, Australia alone excepted (if the Weaver-finches be excluded from this family). All the true Finches have the "conirostral" type of bill, the beak being stout and conical, with a sharp apex, but not having the upper mandible toothed (figs. 424, D, and 425). There are nine primary quill-feathers in the wing. As examples of the *Fringillidæ* may be mentioned the Chaffinches and their allies (*Fringilla*), the House-sparrows (*Pyrgita* or *Passer*), the Goldfinches and Siskins (*Carduelis*), the Bullfinches (*Pyrrhula*), the Linnets (*Linota*), the Greenfinches and Grosbeaks (*Coccothraustes*), the Crossbills (*Loxia*), the Buntings and Yellowhammers (*Emberiza*), and the Hang-nests, or American Orioles (*Icteridæ*).

Fig. 425.—Head of the Common Bullfinch (*Pyrrhula vulgaris*), showing the conirostral beak.

16. *Sturnidæ.*—The birds included in the Starling family have comparatively long straight bills, and have ten primary quill-feathers in the wing, of which the first is short. The feet are large and strong, and are adapted for walking on the ground. The Starlings are found all over the Old World, except in the continent of Australia; and the common Starling (*Sturnus vulgaris*) is a familiar European bird.

17. *Alaudidæ.*—The "Larks" have ten primary quill-feathers, but the

first is rudimentary. The claw of the hind-toe is usually long and straight. The most familiar British species is the Skylark (*Alauda arvensis*).

In addition to the preceding, there are included in the order of the Passerine Birds a number of forms which are songless, mostly ground-loving birds, and which have the so-called "mesomyodian" type of syrinx. With the exception of the family of the Ant-thrushes (*Pittidæ*) of the warmer regions of the Old World, and the singular Lyre-birds (*Menuridæ*) of Australia, all the forms included in this section are found in North and South America. The chief families are the Tyrant-birds (*Tyrannidæ*), the American Ant-thrushes (*Formicariidæ*), the American Chatterers (*Cotingidæ*), and the American Creepers (*Dendrocolaptidæ*).

ORDER XII. PICARIÆ.—The order of the Picarian Birds is a large and ill-defined division, corresponding to the old order of the *Scansores* (exclusive of the Parrots), together with most of the birds formerly included in the "fissirostral" section of the Perching Birds. The sternum of the *Picariæ* is generally furnished with a double notch in its hinder margin on each side, and the hallux is not provided with a separate flexor muscle, as it is in the Passerine Birds. The condition of the foot varies greatly; but two principal types are recognisable. In one of these the foot is of the "scansorial" or "zygodactyle" type, the fourth or outer toe being permanently turned backwards along with the hallux, or being capable of being so reversed (in the Trogons it is the second or inner toe which is thus turned backwards). The foot thus comes to consist of two toes in front and two behind, and is specially adapted for climbing. The other principal type of foot in the *Picariæ* is the so-called "syndactyle" type, in which the two outer toes, and sometimes the inner toe also, are more or less completely united to one another by the skin, the hallux alone being turned backwards. In most of the Swifts, again, the hallux is turned forwards along with the other toes. In other forms, finally, such as the Humming-birds and Hoopoes, the foot more nearly resembles that of the Perchers.

The Picarian Birds are monogamous, and bring forth helpless young. The eggs are mostly white, and the nest is commonly made in a hole in a tree or in a crevice in rocks.

The numerous forms included under the head of *Picariæ* may be briefly considered under the following six principal sections:—

I. CUCULOIDEÆ.—The principal family included in this section is that of the Cuckoos and their allies (*Cuculidæ*). The bill in the Cuckoos is of moderate length, with a wide gape, the nostrils being placed low down in

a groove. The outer toe is reversible, but the Cuckoos, though living in wooded districts, are not climbing birds. The Cuckoos are found in all the warmer regions of the globe, and are remarkable for the habit which many of them possess of laying their eggs in the nests of other birds, instead of nidificating and incubating on their own account. This habit seems to be connected, in part at any rate, with the fact that the successive eggs are laid at prolonged intervals. The only bird not belonging to the Cuckoos which is known to have the same "parasitic" habit, is the Cow-bunting (*Molothrus pecoris*) of the United States. As a rule, only one egg is deposited in each nest, and the young Cuckoo which is hatched from it is brought up by the foster-parent, generally at the expense of the legitimate offspring. A number of Cuckoos, however, build nests for themselves in the ordinary manner; and it is noticeable that in some of these cases, at any rate (as, for example, in the *Coccyzus americanus* or Yellow-billed Cuckoo of the United States), the successive eggs are laid at considerable intervals, so that well-developed young may be found in the same nest with a fresh-laid egg.

The common British Cuckoo is the *Cuculus canorus*. The common Cuckoos of the United States belong to the genus *Coccyzus*. The largest of the Cuckoos is the great Channel-bill (*Scythrops Novæ-Hollandiæ*) of Australia. More or less nearly allied to the Cuckoos are the Honey-guides (*Indicatoridæ*) and the Plantain-eaters (*Musophagidæ*), all the members of which are found in the warmer parts of the Old World.

II. CAPRIMULGOIDEÆ.—The principal family included here is that of the *Caprimulgidæ* or Goatsuckers, in which the beak is of the typical "fissirostral" form (fig. 426), being short and remarkably wide in its gape, its hinder margin being fenced in by a number of bristles (*vibrissæ*). The Goatsuckers, as represented by the common European Night-jar (*Caprimulgus europæus*), are insectivorous, nocturnal, and in some respects Owl-like birds. They have a lax and soft plumage, large eyes, and a hawking flight. The feet are short and weak, and the middle toe has a serrated claw. A well-known American Night-jar is the Whip-poor-will (*Antrostomus vociferus*); and a familiar Australian form, belonging to an allied family, is the "Morepork" (*Podargus Cuvieri*). A more remarkable type, also representing a distinct family, is the Guacharo bird (*Steatornis caripensis*) of Central America and Trinidad.

Fig. 426.—Head of Goatsucker (*Caprimulgus*), showing the fissirostral form of beak.

III. ALCEDINOIDEÆ.—The two most characteristic families included in this section are the Kingfishers (*Alcedinidæ*), and the Bee-eaters (*Meropidæ*). The Kingfishers are distinguished by their long and powerful, generally angular bill, and short weak legs. The foot is of the "syndactyle" type, the outer and middle toes being united along almost their entire length. The common Kingfisher (*Alcedo ispida*) feeds upon small fish, which it captures by dashing into the water from some elevated station. Many other Kingfishers have the same habit; but some, such as the Laughing Jackass (*Dacelo gigas*) of Australia, are principally insect-

feeders. A very beautiful North American species is the Belted Kingfisher (*Ceryle alcyon*).

The Bee-eaters (*Meropidæ*) are entirely confined to the Old World, and resemble the Kingfishers in having a "syndactyle" foot. They have long curved and pointed bills, and feed upon insects. Allied to the preceding are the Motmots (*Momotidæ*) of Central and Southern America, and the Todies (*Todidæ*) of the West Indian Islands.

A more remarkable group of birds which may be placed here, is that of the Hornbills (*Bucerotidæ*). The Hornbills are large birds, with very large bills surmounted by a kind of crest or helmet-shaped structure, composed of bone rendered light by the presence of numerous air-cells. The foot is of the "syndactyle" type. The Hornbills are exclusively confined to the hotter regions of the Old World, and they live for the most part upon fruits. A well-known species is the Rhinoceros Hornbill (*Buceros rhinoceros*) of Malacca and Borneo. The nests are usually made in trees, and the male has the curious habit of imprisoning the female within the nest during the period of incubation, by plastering up the external opening of the nest with mud, leaving only a small aperture through which he supplies food to the mother and offspring.

Related to the Hornbills, though totally unlike them in appearance, are the elegant birds which form the family of the Hoopoes (*Upupidæ*). Only the single genus *Upupa* is known, including some half-a-dozen species, all of which are found in the Old World. The common Hoopoe (*Upupa epops*) is an inhabitant of the continent of Europe, and occasion-

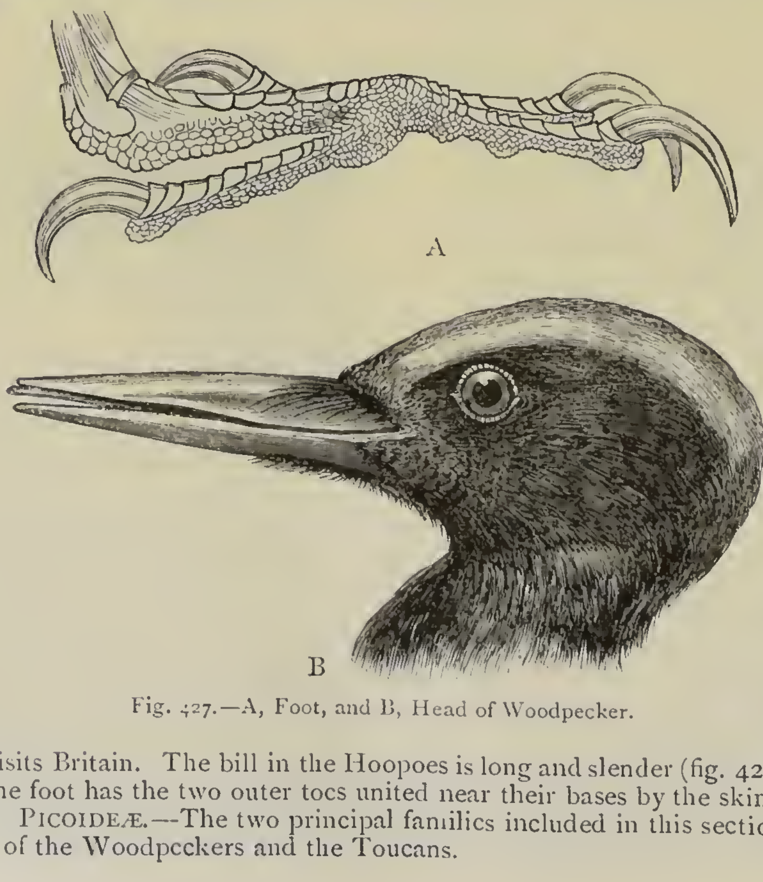

Fig. 427.—A, Foot, and B, Head of Woodpecker.

ally visits Britain. The bill in the Hoopoes is long and slender (fig. 424, A), and the foot has the two outer toes united near their bases by the skin.

IV. Picoideæ.—The two principal families included in this section are those of the Woodpeckers and the Toucans.

The Woodpeckers (*Picidæ*) are thoroughly adapted for climbing, as also for obtaining the insects on which they feed from under the bark of trees or in decayed wood. The foot is "seansorial," the outer toe being turned back along with the hallux, and the claws are crooked and sharp-pointed (fig. 427, A). The beak is of large size, and is pointed or wedge-shaped (fig. 427, B), being suited for the excavation of wood by repeated blows. The tail-feathers, in the typical members of the group, terminate in stiff pointed ends, and assist the bird in running up the trunks of trees. The tongue is very long and extensible, and is barbed at its point; the great cornua of the hyoid bone being of great length, and bending over the back and top of the skull to be attached anteriorly near the base of the upper mandible. The bird catches insects by transfixing them with its protrusible tongue, the operation being facilitated by the copious supply of viscid saliva poured into the mouth by the greatly developed salivary glands. The Woodpeckers nest in holes in trees, and are unsociable, untamable birds, often beautifully coloured, and given to wandering from place to place. They are represented in all regions except Australia. Allied to the Woodpeckers proper, but having the quill-feathers of the tail flexible and soft, are the Wry-necks (*Yunx*), the species of which are found in the Palæarctic and Ethiopian provinces. Some authorities likewise place the Barbets (*Bucconidæ*) of Neotropical regions in the neighbourhood of the Woodpeckers.

The Toucans (*Rhamphastidæ*) form a remarkable group of birds which agree with the Woodpeckers in having a strictly "scansorial" foot, the outer toe being turned back along with the hallux. Their most remarkable character, however, is to be found in the form of the bill, which is very large, longer than the head, and sometimes of comparatively gigantic size (fig. 428). The mandibles are, however, to a very great extent

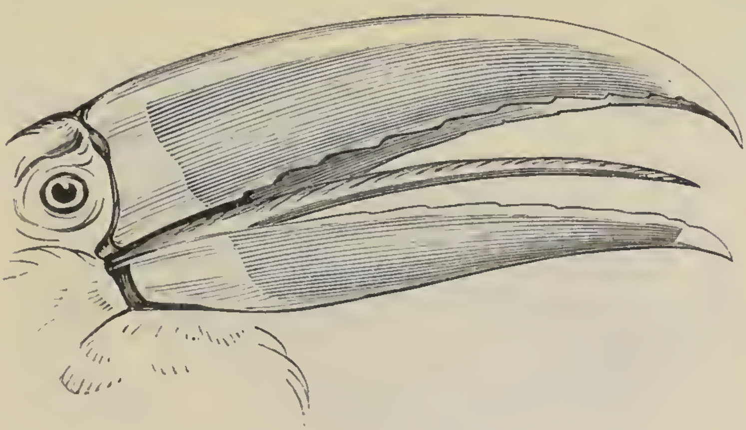

Fig. 428.—Head of Toucan.

hollowed out into air-cells, so that the weight of the bill is much less than would be anticipated from its size. The tongue is very long, notched at its side, or feathered with delicate lateral processes. The Toucans live upon fruits, and are all confined to the Neotropical province, frequenting forests in considerable flocks.

V. TROGONOIDEÆ.—This section includes only the Trogons (*Trogonidæ*)—birds of beautiful plumage, which inhabit the forests of the intertropical regions of both the Old and New World. The Trogons in some respects

resemble the Goatsuckers, having short depressed bills, with a very wide gape, which is bordered behind by bristles. The legs are short and weak, and the foot is "scansorial," but differs from that of the *Picoideæ* in the fact that it is the inner or second toe that is turned back along with the hallux. The Trogons, in spite of the structure of the foot, are poor climbers, and their food may be insects only, or of a mixed kind.

VI. CYPSELOIDEÆ.—This section includes the two families of the Swifts (*Cypselidæ*) and the Humming-birds (*Trochilidæ*). The Swifts are swallow-like birds, with long pointed wings and a remarkable power of rapid and prolonged flight. The bill (fig. 424, C) is of the "fissirostral" type, being short, depressed, and weak, with a wide gape fringed by bristles. The legs are very short and weak, with short feeble toes, the hallux being in most cases turned forward along with the three anterior toes. The Swifts are almost universally distributed, being absent from New Zealand; and a familiar type is the common Swift (*Cypselus apus*).

The Humming-birds (*Trochilidæ*) are in many respects allied to the Swifts, but are in other respects an extremely well-defined group. Nearly four hundred species of Humming-birds are known, all of small size, and including the most fragile and brightly coloured of all the birds, some not weighing more than twenty grains when alive, and many exhibiting the most brilliant play of metallic colours. The Humming-birds are pre-eminently South American, but extend northwards as far even as the southern portions of Canada. The bill is always very long and slender, as are the toes also. The tongue is long, protrusible, and deeply cleft, its tip being brush-like or papillose, and it appears to be used either to catch insects within the corollas of flowers, or to suck up the juices of the flowers themselves. The plumage of the males is always brilliant, with metallic reflections, that of the females generally comparatively sombre. The legs are short and weak, but the wings are proportionately very long, and the flight is exceedingly rapid.

ORDER XIII. PSITTACI.—This order includes the Parrots, and is characterised by the fact that the upper mandible of

Fig. 429.—A, Skull of a Parrot (*Psittacus erythacus*). B, Foot of the same: *a* Hallux; *b* Index; *c* Middle toe; *d* Outer or ring toe. (After Blanchard.)

the bill (fig. 430) is strongly arched and hooked at its tip, the nostrils being pierced in a cere at its base. The lower mandible of the beak is shorter than the upper one, within which it bites, and it is also hooked at its tip. The upper mandible is articulated with the skull by a hinge-joint, great

mobility of the beak being thus conditioned. The palate is largely completed by bone, and the vomer is wanting. The tongue is thick and fleshy, in some cases (*Trichoglossus*) terminated by brush-like papillæ. The legs are feathered down to the short tarso-metatarsus, and the foot (fig. 429) is of the thoroughly "scansorial" type, the outer toe being turned backwards along with the hallux. The claws are curved, and the bill is used as a kind of third foot, the feet being thus allowed to be employed in prehension. The clavicles are weak, often not united to form a furcula, and sometimes absent. The sternum is without notches in its hinder margin.

The Parrots are arboreal, fruit-eating birds, which inhabit the warmer regions of the Old and New Worlds, and of which about four hundred species are known. Their plumage is generally bright and gaudy in its coloration, and their voice is mostly harsh, grating, and dissonant. They are mostly sociable in their habits, are monogamous, make their nests chiefly in holes in trees, and bring forth helpless young. In many respects the Parrots may claim to be regarded as the highest group of the birds.

The following are the principal families of the *Psittaci* :—

1. *Plyctolophidæ.*—This group includes the "Cockatoos," which are exclusively confined to the Australian province, and are in general easily recognised by the possession of an erectile crest of feathers on the head (fig. 430).

Fig. 430. Head of Cockatoo.

2. *Psittacidæ.*—This family includes the true Parrots, familiarly exemplified by the Grey Parrot (*Psittacus erythacus*) of Africa, which is commonly kept as a domestic pet. The true Parrots are mainly African, but some forms are found in the Neotropical province.

3. *Conuridæ.*—This family includes the "Macaws" (*Ara*, &c.), which are distinguished by their long tails, and are wholly confined to the Neotropical province and the warmer parts of North America.

4. *Platycercidæ.*—The forms included in this family are nearly related to the preceding, and are usually known as "Parrakeets." The typical members of the group are confined to the Australian province.

5. *Trichoglossidæ.*—This family comprises the Brush-tongued Parrots (*Trichoglossus*) and Lories, all of which are found in the Australian province.

6. *Nestoridæ.*—This family comprises only the single genus *Nestor*, which is confined to New Zealand and Norfolk Island. The Philip Island Parrot (*Nestor productus*) has not been found alive since the year 1851.

7. *Strigopidæ.*—This family includes only the singular "Kakapo" or "Owl-parrot" (*Strigops habroptilus*, fig. 431) of New Zealand. The head

Fig. 431.—The Owl-Parrot (*Strigops habroptilus*), New Zealand.

of the Kakapo is Owl-like; and though its wings are well developed, it does not appear to use them for flight. In fact, the keel upon the sternum is rudimentary, and the clavicles are wanting. Unlike the ordinary Parrots, the *Strigops* is a solitary bird, which is only active by night, spending the day in holes in rocks or in burrows in the ground.

ORDER XIV. RAPTORES or ACCIPITRES.—The "Birds of Prey," which form this order, are characterised by the shape of the bill, which is sharp-edged and sharp-pointed, and is adapted for killing animals, or for tearing up flesh. The upper mandible is the longest (fig. 432), and is strongly hooked at its tip. The base of the upper mandible is furnished with a fleshy "cere," in which the nostrils are pierced. The body is very muscular, and the legs are usually short and robust, the feet

being powerful, with three anterior toes and a backwardly directed hallux, all provided with long curved claws or talons. The wings are mostly pointed, and of considerable size, and the flight is usually rapid and powerful. The clavicles are well developed, and the sternum has a large carina. The

Fig. 432.—Head of Sea-Eagle (*Haliaëtus*). *a* Supraciliary ridge; *b* Cere, in which the nostrils are pierced. (After Keulemans.)

crop is present, except in Owls, and the gizzard is thin and membranous.

The Birds of Prey are monogamous, and the females are usually larger than the males. They generally build their nests in lofty and inaccessible situations, and rarely lay more than four eggs, from which the young are liberated in a naked and helpless condition.

The Birds of Prey have been often divided into the two sections of the *Nocturnal* and *Diurnal* Raptores, but the division is not a satisfactory one, as some of the Owls are active by day. By Mr Bowdler Sharpe the order is divided into the three primary divisions of the *Striges* (Owls), the *Falcones* (Hawks, Eagles, Vultures), and the *Pandiones* (Ospreys), the characters and chief groups of which may be briefly noticed.

Section I. Striges.—Outer toe *reversible;* tibia twice as long as the tarsus; body-feathers without an after-shaft; plumage soft; a facial disc present.

This section includes only the Owls, the majority of which are nocturnal in their habits. The foot in the Owls has the outer toe reversible, or capable of being turned backwards along with the hallux (fig. 433, A). The tarso-metatarsus is short, about half the length of the tibia, and it is usually feathered, as also commonly are the toes. All the toes are furnished with powerful hooked talons. The eyes are of large size, and are directed forwards, the feathers of the face being disposed so as to form a complete or incomplete "disc" round each eye (fig. 433, B). The clothing-feathers have no after-shafts, and the plumage is exceedingly loose and soft, so that the flight, even of the large species, is almost noiseless. Very commonly the plumage is spotted or barred with different shades of grey,

brown, or yellow. The beak is strongly hooked, and furnished at its base with bristles, which more or less conceal the "cere" in which the nostrils are pierced. The cranial bones are highly pneumatic, and the skull is therefore of large size. Very often there is an auricular tuft of feathers round the external meatus auditorius, which may be further protected by a flap of skin. The œsophagus is not dilated into a crop, and the indiges-

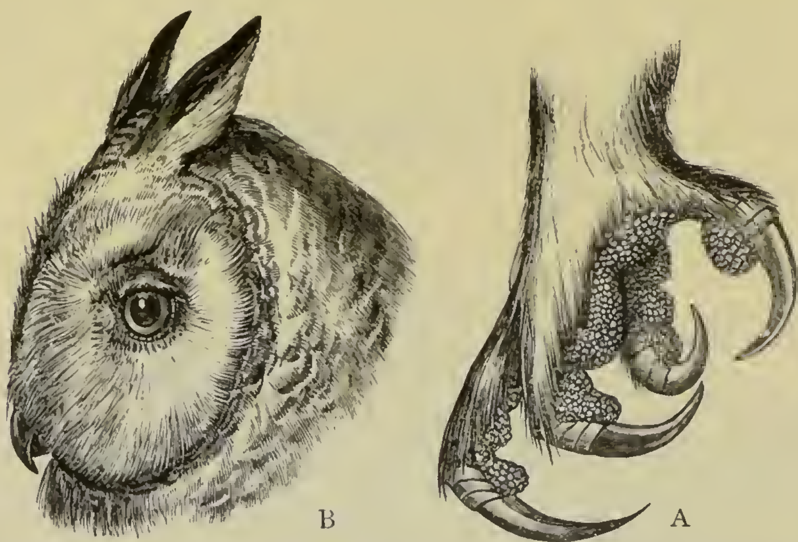

Fig. 433.—A, Foot of the Long-eared Owl (*Otus vulgaris*); B, Head of the same.

tible portions of the food are rejected by regurgitation from the stomach in the form of small pellets. The Owls mostly hunt the small vertebrate animals, which constitute their chief food, by twilight; but there are species which hunt by day. The Owls have a universal distribution,—the two commonest British species being the Barn Owl (*Strix flammea*) and the Tawny Owl (*Syrnium stridula*), representing respectively the two families (*Strigidæ* and *Bubonidæ*) into which Mr Sharpe divides the *Striges*.

SECTION II. PANDIONES.—Outer toe *reversible;* tibia double the length of the tarsus; body-feathers without an after-shaft; plumage compact; no facial disc. This section comprises only the single genus *Pandion*, which approaches the Owls in the possession of a reversible outer toe, the absence of after-shafts to the contour-feathers, and the proportions of the tibia and tarso-metatarsus, while it resembles the Falcons in the compact character of the plumage and the absence of a facial disc. The only species known is the Osprey or Fishing-eagle (*Pandion haliaëtus*), which is found almost all over the world, and lives entirely upon fish.

SECTION III. FALCONES.—Outer toe not reversible; tibia varying in length in proportion to the tarsus, sometimes equal to it, but never double the length of the latter; body-feathers

(except in the *Cathartidæ*) without after-shafts; plumage compact (Bowdler Sharpe). This section includes the Hawks, Falcons, and Eagles, the Old World Vultures, the American Vultures, and the Secretary Birds, the following being the principal families:—

1. *Falconidæ.*—In this family the head and neck are always clothed with feathers, and the eyes are more or less sunk in the head, and are provided with a supraciliary ridge or eyebrow (fig. 432). It is to a great extent to the presence of this ridge that these birds owe their bold and fearless expression. The plumage is firm and compact, and the contour-feathers have after-shafts. The wings are long and pointed, and the tarso-metatarsus is generally bare, though the leg is feathered to the toes in the great Bearded Eagle or Lämmergeier (*Gypaëtus barbatus*). This family is divided into a number of sub-families, corresponding, in a general way, with the groups of Raptorial birds commonly known as Hawks, Buzzards, Falcons, and Eagles.

2. *Vulturidæ.*—This family includes the Vultures of the Old World, characterised by the fact that the head and neck are naked or covered only with down, the eyes are without supraciliary ridges, the nostrils are separated by a bony septum, and the feathers have after-shafts. The Vultures are large carrion-feeding birds, which inhabit the hotter regions of the Old World generally. Well-known forms are the Egyptian Vulture (*Neophron percnopterus*), the Black Vulture (*Vultur monachus*), and the Griffon Vulture (*Gyps fulvus*).

3. *Cathartidæ.*—The "American Vultures" included in this family are distinguished from the Vultures of the Old World by having no after-shafts to the clothing-feathers, and by the fact that the nostrils are perforated from side to side; while they agree with the latter in the absence of eyebrows, and in having the head and upper part of the neck unfeathered. The bill is not powerfully raptorial; the talons are blunt and little curved; and the gullet has a very capacious crop. The American Vultures feed principally upon carrion, and are mostly cowardly and comparatively sluggish birds. The wings, however, are long and strong, and they possess great powers of flight. This group comprises the Californian Vulture (*Cathartes californianus*) of Western North America, the King Vulture (*Sarcorhamphus papa*) of tropical America, and the famous and gigantic Condor (*Sarcorhamphus gryphus*) of South America.

4. *Gypogeranidæ.*—This family includes only the single genus *Gypogeranus* or *Serpentarius*, comprising only the curious "Secretary Vulture" (*S. secretarius*) of Africa. This singular bird differs from the *Raptores*, generally, in the great elongation of the legs, the lower part of which is naked and unfeathered. The wings are long, and are armed with blunt spurs. The Secretary Bird lives principally upon snakes and other reptiles, which it kills by repeated and powerful blows with its feet, protecting itself the while by its outspread wings. In many of its characters the Secretary Bird differs from the *Raptores*, and its true place in the system is still a matter of dispute among ornithologists.

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DIVISION III.—MAMMALIA.

CHAPTER LXIII.

GENERAL CHARACTERS OF THE MAMMALIA.

THE Quadrupeds or *Mammalia* constitute the highest class of the *Vertebrata*, and may be shortly defined as *hot-blooded vertebrate animals in which the epidermic exoskeleton is in the form of hairs and never of feathers, and in which the young are nourished for a longer or shorter time after birth by means of a special fluid—the milk,—secreted by special glands—the mammary glands.* These characters are of themselves sufficient broadly to separate the Mammals from all other classes of the vertebrate sub-kingdom. In addition, however, to these leading peculiarities, the Mammals exhibit the following further general characters of scarcely less importance:—

The skull articulates with the vertebral column by two occipital condyles.

The mandible consists of two rami, each of which consists of but a single piece; and the mandible further articulates with the squamosal element of the skull directly, and not by the intervention of a quadrate bone. A corpus callosum is present in the brain. The heart is four-chambered, the right and left sides of the heart are completely separated from each other, and the pulmonary and systemic circulations only communicate through the medium of the capillaries. The red blood-corpuscles are non-nucleated, and, with the exception of those of the *Camelidæ*, have the form of circular biconcave discs. There is only one aorta—the left—which turns over the left bronchus.

The cavities of the thorax and abdomen are separated by a complete muscular partition or diaphragm.

The respiratory organs are in the form of two lungs sus-

pended in the thorax, but none of the bronchi end in air-receptacles distributed through the body.

The visceral arches of the embryo never develop branchiæ.

The structures known as the "amnion" and "allantois" are always present in the embryo. The allantois, however, either disappears at an early period of life, or it develops a vascular organ which serves as a means of communication between the maternal and fœtal circulations, and which is known as the "placenta."

With the exception of the Monotremes, the Mammals are all viviparous.

The above are the essential characters which distinguish the *Mammalia* as a class; but it is necessary to consider these, and some other points, in a more detailed manner.

With regard, in the first place, to the *exoskeleton* of Mammals, the most characteristic structures are the epidermic appendages known as "hairs." These are formed upon papillæ of the dermis, sunk in saccular involutions of the skin ("hair-follicles"), and they are different from feathers in the fact that the producing papilla is not grooved, and the cap of epidermis thrown off from it does not, therefore, split up in the process of growth. The spines of such Mammals as the Porcupine and Hedgehog are merely rigid hairs. In some cases, the epidermic appendages take the form of horny scales, as seen in the large scales of the Pangolins (*Manis*), and the small scales on the tails of Mice, Rats, and some other Mammals. Some of the Cetaceans appear to be wholly without hair in the adult state; but most of the apparently hairless Whales possess a small number of scattered hairs; and others (*e.g.*, Dolphins) exhibit tufts of hair upon the muzzle in the fœtal condition. Besides hair, hardenings of the epidermis may give rise to claws, hoofs, and nails, or to such structures as the sheaths of the horns in the Cavicorn Ruminants. Except in the case of the Armadillos, in which an armour of bony dermal plates is developed, the dermis of the *Mammalia* does not develop any exoskeletal structures.

With regard to the *endoskeleton* of the *Mammalia*, the following points may be briefly noticed:—

With the exception of the Whales and Dolphins (*Cetacea*), and the Dugongs and Manatees (*Sirenia*), the vertebral column is divisible into the same regions as in man—namely, into a cervical, dorsal, lumbar, sacral, and caudal or coccygeal region (fig. 434). In the *Cetacea* and *Sirenia* the dorsal region of the spine is followed by a number of vertebræ which compose the hinder extremity of the body, but

which cannot be separated into lumbar, sacral, and caudal vertebræ.

In spite of the great difference which is observable in the length of the neck in different Mammals, the number of

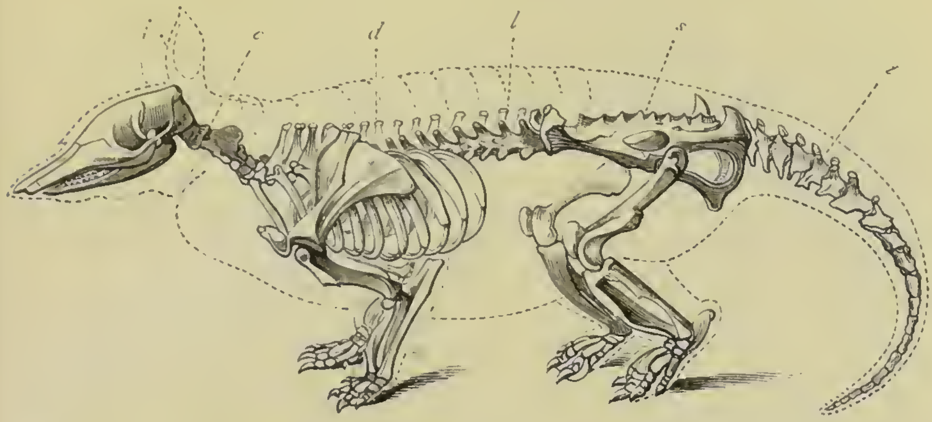


Fig. 434.—Skeleton of an Armadillo, showing the regions of the vertebral column. *c* Cervical region; *d* Dorsal region; *l* Lumbar region; *s* Sacral region; *t* Caudal region or tail.

vertebræ in the cervical region is extraordinarily constant, being almost invariably seven, as in man. In this respect there is no difference between the Whale and the Giraffe. The only exceptions to this law are the Manatees (*Manatus*), which have but six cervical vertebræ; the three-toed Sloths (*Bradypus*), which are commonly regarded as possessing nine, though competent anatomists would refer the posterior two of these to the dorsal region; and one of the two-toed Sloths (*Cholœpus Hoffmanni*), which has only six cervical vertebræ.

The dorsal vertebræ are mostly thirteen in number, but they vary from ten to twenty-four. In man there are twelve, in one of the Armadillos only ten, and in the two-toed Sloths and the *Hyrax* the maximum is attained. The lumbar vertebræ are usually six or seven in number, rarely fewer than four. In Man they are five in number, and they are reduced to three in the Great Ant-eater (*Myrmecophaga*) and to two in the Little Ant-eater (*Cyclothurus*).

The first vertebra, or atlas, always bears two articular cavities for the reception of the two condyles of the occipital bone; and the second vertebra, or axis, usually has an "odontoid" process on which the head rotates. In the true Whales, however, in which the cervical vertebræ are anchylosed together to a greater or less extent, and the neck is immovable, the odontoid process is also wanting.

In almost all Mammals the spinous processes of the dorsal vertebræ are very largely developed for the attachment of the structure which is known as the *ligamentum nuchæ.* This is a great band of elastic fibrous tissue, which is attached in front to the occipital bone and spinous processes of the cervical vertebræ, and which relieves the muscles of the task of supporting the head in those Mammals which progress with the body in a horizontal position. The development of the *ligamentum nuchæ* is consequently, as a rule, proportionate to the size of the head and the length of the neck. In Whales no such apparatus is necessary, owing to the fixation of the cervical vertebræ by anchylosis; and in Man, who walks erect, the *ligamentum nuchæ* can hardly be said to exist as a distinct structure, being merely represented by a band of fascia.

The number of lumbar and sacral vertebræ, as we have seen, varies in different Mammals; but ordinarily some of the vertebræ are anchylosed into a single bone, and have the iliac bones abutting against them, thus constituting the "sacrum" of human anatomists. In the *Cetacea* and *Sirenia*, in which the hind-limbs are wanting, and the pelvis rudimentary, there is no "sacrum."

The thoracic cavity or chest in Mammals is always enclosed by a series of ribs, the number of which varies with that of the dorsal vertebræ. In most cases each rib articulates by its head with the bodies of *two* vertebræ, and by its tubercle with the transverse process of one of these vertebræ (the lower one). In the *Monotremata* (*e.g.*, the Duck-mole), the ribs articulate with the body of the vertebra only; and in the Whales, the hindermost of the ribs, or all of them, articulate with the transverse processes only, and not with the centra at all.

There are usually no bony pieces uniting the ribs with the sternum or breast-bone in front, as in Birds; but the so-called "sternal ribs" of *Aves* are represented by the "costal cartilages" of the Mammals. In some cases, however, the cartilages of the ribs do become ossified and constitute sternal ribs. Sometimes, as in the Armadillos, there is a joint between the vertebral ribs and sternal ribs. More rarely, as in the *Monotremes* (fig. 441, D), an intermediate piece is found between the vertebral and sternal portions of the rib. Only the anterior ribs reach the sternum, and these are called the "true" ribs; the posterior ribs, which fall short of the breastbone, being known as the "false" ribs.

The sternum or breast-bone (fig. 435) is formed of several pieces placed one behind the other, but usually anchylosed together to form a single bone. It is placed upon the ventral

surface of the body, and is united with the vertebral column by the ribs and their cartilages. It is generally a long and narrow bone, but in the *Cetacea* it is broad. It is only in some burrowing animals (such as the Moles) and in the true flying

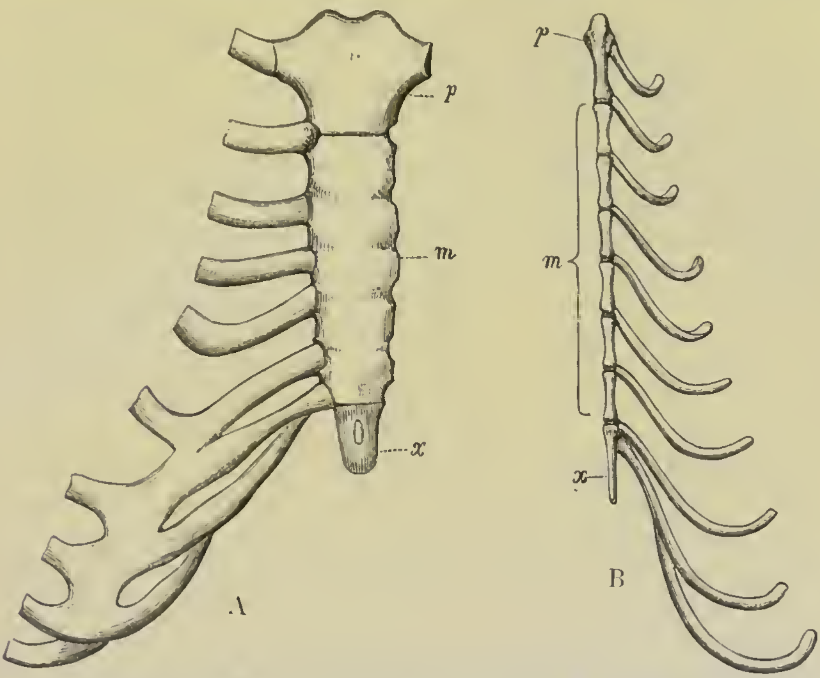


Fig. 435.—A, Sternum of Man, with the costal cartilages. B, Sternum and costal cartilages of the Dog: *p* Præsternum; *m* Mesosternum; *x* Xiphisternum.

Mammals (the Bats), that the sternum is provided with any ridge or keel for the attachment of the pectoral muscles, as it is in Birds. The sternum is primitively composed of three pieces, an anterior piece or *præsternum*, a middle piece or *mesosternum*, and a posterior piece or *xiphisternum*. The præsternum is the "manubrium sterni" of human anatomy, and is the portion of the sternum which lies in front of the attachment of the second pair of ribs. All the other ribs are connected with the mesosternum. The *xiphisternum* is the "xiphoid cartilage" of human anatomy, and it commonly remains throughout life more or less unossified. In the Monotremes there is a T-shaped bone above or in front of the præsternum, but this is to be regarded as belonging to the shoulder-girdle, and as representing the "episternum" or "interclavicle" of the Reptiles.

The normal number of limbs in the *Mammalia* is four, two anterior and two posterior; and hence they are often spoken of as "quadrupeds," though all the limbs are not universally

present, and other animals have four limbs as well. The anterior limbs are not known to be wanting in any Mammal, but the posterior limbs are absent in the *Cetacea* and *Sirenia*, which are hence sometimes spoken of as the "mutilated Mammals."

As regards the structure of the anterior limb, the chief points to be noticed concern the means by which it is connected with the trunk. The scapula or shoulder-blade is never absent, and it is in the form of a broad flat bone (rarely long and narrow), applied to the outer aspect of the ribs, and much more developed than in the Birds. The coracoid bone, which forms such a marked feature in the scapular arch of *Aves*, is, in the majority of Mammals, fused with the scapula, of which it forms the "coracoid process." In the Monotremes only is the coracoid a separate bone which articulates with the top of the sternum. The collar-bones or clavicles never unite in any Mammal to form a "furcula," as in Birds; but in the Monotremes they unite with an "interclavicle" placed in front of the sternum. The clavicles, in point of fact, are not present in a well-developed form in any Mammals except in those which use the anterior limbs in flight, in digging, or in prehension. The *Cetacea*, the Hoofed Quadrupeds (*Ungulata*), and some of the *Edentata*, have no clavicles. Many of the *Carnivora* and some Rodents possess an imperfect clavicle, which does not articulate with the top of the sternum. The Insectivorous Mammals, many of the Rodents, the Bats, and all the Monkeys, have (with Man) a perfect clavicle articulating with the anterior end of the sternum.

The humerus, or long bone of the upper arm (*brachium*), is never wanting, but it is extremely short in the Whales, in which the anterior limbs are converted into swimming-paddles. In some Mammals, as in certain Monkeys, and in the *Felidæ* (constituting the most typical group of the *Carnivora*), the median nerve and brachial artery are protected on their way down the arm by a canal placed a little above the elbow, and formed by a process—the "supracondyloid" process—which is sometimes present in man as an abnormality.

In the fore-arm of all Mammals the ulna and radius are recognisable, but they are not necessarily distinct; and the radius, as being the bone which mainly supports the hand, is the only one which is always well developed, the ulna being often rudimentary. The condition of the ulna, indeed, varies much, even in the limits of a single order. Thus some Ungulates (*e.g.*, Pig) have a complete ulna, while in others (Ruminants) the ulna is rudimentary, or, as in Camels, is

anchylosed with the radius. In the flying Mammals or Bats, the ulna is hardly recognisable, being reduced to its upper third and fused with the radius. The fore-arm attains its greatest perfection in man, in whom the radius can rotate upon the ulna, so as to allow the back of the hand to be placed upwards or downwards, these movements being known respectively as "pronation" and "supination." In the Monkeys only is there any approach to this power of rotation.

The condition of the bones of the wrist or "carpus" departs considerably from what it is in its most generalised form. The typical arrangement of the carpus (fig. 436) is that there should be a proximal row of carpals and a distal row of carpals, separated by a single bone ("os centrale") placed between the two. The upper or proximal row of carpals should consist of a radial carpal, an ulnar carpal, and an intermediate carpal (fig. 436, *r*, *u*, *i*). The lower or distal row should consist of five carpals, carrying the five metacarpals of the digits. In the Mammalian carpus, though the above general type is readily recognisable, the central bone of the carpus is commonly wanting, and the 4th and 5th carpals of the distal row of carpals always anchylose with one another to form a single bone (the "unciform"). Moreover, it is usual to find a sesamoid bone (the "pisiform" bone) developed upon the ulnar side of the proximal row of carpals, and a corresponding sesamoid bone may be developed upon the radial side of the same row.

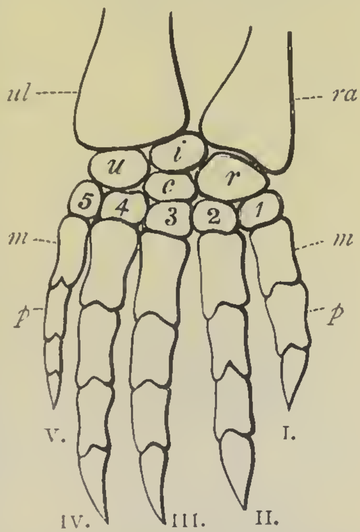


Fig. 436.—Right manus of a Chelonian (*Chelydra*), viewed dorsally, (after Gegenbaur). *ra* Radius; *ul* Ulna; *r* Radial carpal; *u* Ulnar carpal; *i* Intermediate carpal; *c* Central carpal; 1–5. The five carpals of the distal row, corresponding with the five digits; *m m* Metacarpals; *p p* First row of phalanges. I. Pollex; II. Index; III. Medius; IV. Annularis; V. Minimus.

The normal number of digits in the manus is five, and though this number is often reduced, it is never exceeded. The number of metacarpals corresponds with that of the digits, though this condition of parts may be obscured by anchylosis. Thus, in the Ruminants generally (fig. 437), in which the manus has only two functional toes (the 3d and 4th), there appears to be only a single elongated metacarpal (the "can-

non-bone"). This consists, however, in reality of the 3d and 4th metacarpals, which are distinct from one another in the embryo, but become fused with one another in the adult. On the other hand, in the Horse (fig. 438), in which the only

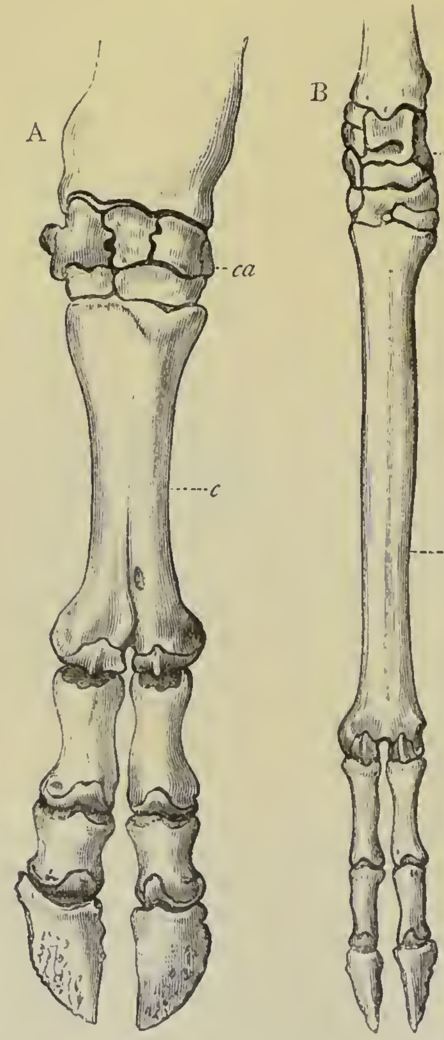


Fig. 437.—A, Fore-leg of Ox (*Bos taurus*). B, Hind-leg of Stag (*Cervus elaphus*). *ca* Carpus; *ta* Tarsus; *c* "Cannon-bone," composed of the united metacarpals or metatarsals of the 3d and 4th digits.

Fig. 438.—Fore-leg of Horse. *ca* Carpus; *m* Metacarpal of the third digit; *s* "Splint-bone," or rudimentary metacarpal; 1. First phalanx, or "great pastern"; 2. Second phalanx, or "small pastern"; 3. Third phalanx, or "coffin-bone."

functional toe is the 3d, the so-called "cannon-bone" is really a single bone, and is the greatly elongated 3d metacarpal. The so-called "splint-bones" of the Horse (fig. 438, *s*) represent the rudimentary metacarpals of the 2d and 4th

digits, but they only have the form of long spines placed behind the upper end of the great 3d metacarpal.

While the normal number of five digits to the manus is never exceeded, many Mammals have fewer than this number. The digit which is most liable to undergo suppression is the innermost digit—the thumb or "pollex." This digit is wanting in all existing types of the Ungulate Mammals. The digit which shows the next greatest liability to suppression is the outermost digit of the hand—the little finger, or "minimus." When this digit is wanting as well as the pollex, the manus becomes three-toed, as in the Rhinoceroses. Should further reduction take place, the next digit to be suppressed is again the radial or inner digit—viz., the "index" or forefinger. The manus thus comes to consist only of the 3d and 4th toes, as in some Ruminants. [These are the two functional toes in all Ruminants, but the 2d and 4th are often present in a rudimentary form.] Should still further reduction take place, it is now the ulnar or outer digit which disappears—viz., the ring-finger or "annularis." The manus thus may become reduced to the 3d or middle finger ("medius") only, a state of things which occurs in the Horse (fig. 438).

Normally each digit has three phalanges, except the thumb, which has only two. In the Whales and Dolphins (*Cetacea*), in which the anterior limbs form swimming-paddles very like those of the *Ichthyosaurus* and *Plesiosaurus*, the phalanges are considerably increased in number, as they are in those Reptiles. In all the Mammalia, too, except the *Cetacea*, it is the general rule that the terminal phalanx in each digit should carry a nail, claw, or hoof.

While the anterior limbs are never absent in any Mammal, the posterior limbs may be wanting, or represented only by internal rudiments—this occurring, however, only in the *Cetacea* and *Sirenia*. Generally speaking, however, the hind-limbs and their arches are completely developed. The two halves of the pelvis—the ossa innominata—consist each of three pieces in the embryo—viz., the ilium, ischium, and pubes—which meet to form the cup-shaped cavity known as the "acetabulum," with which the head of the thigh-bone articulates. In the adult Mammal (except in Monotremes) these three bones are anchylosed together; and the two ossa innominata generally unite in front by means of a symphysis, constituted either by a cartilaginous union (synchondrosis), or by merely ligamentous attachment. In some Mammals, however, such as the Mole, and many of the Bats, the pubic bones remain disunited during life. As a rule, also, the ossa innominata are firmly united

with the vertebral column. In the Cetaceans, in which the hind-limbs are wanting or rudimentary, and there is no sacrum, the innominate bones are rudimentary, and are not attached in any way to the spine.

In Marsupials and Monotremes are found two small slender bones (rarely cartilages) attached to the brim of the pelvis, and known as the "marsupial bones." These do not belong to the proper skeleton, but are ossifications of the internal tendons of the "external oblique" muscles of the abdomen.

As regards the structure of the hind-limb in Mammals, the thigh-bone or femur articulates with the pelvis, usually at a very open angle. In Man it is distinguished by being the longest bone of the body, and by having the axis of its shaft nearly parallel to that of the vertebral column. In most Mammals the femur is relatively shorter, and the axis of its shaft deviates considerably from that of the spine, being sometimes at right angles, or even at an acute angle.

Of the bones of the leg proper (*crus*) the tibia corresponds to the radius in the fore-limb, as shown by its carrying the tarsus; and the fibula is the representative of the ulna. The articulation between the tibia and fibula on the one hand, and the femur on the other, constitutes the "knee-joint," which is usually defended in front by the "knee-pan" or patella, a large sesamoid bone developed in the tendons of the great extensor muscles of the thigh. The patella is of small size in the *Carnivora*, but does not appear to be wanting in any Mammals except in some of the Marsupials. In many cases the tibia and fibula are anchylosed towards their distal extremities. In the Horse the fibula has much the same character as in Birds, being a long splint-like bone which only extends about half-way down the tibia. In the Ruminants the reverse of this obtains, the upper portion of the fibula being absent, and only its lower extremity present.

The tarsus is constructed upon the same general plan as the carpus, consisting, in its most generalised form, of a proximal row of tarsals, a distal row of tarsals, and a central tarsal between the two rows. The proximal row of tarsals in the Mammals never consists, however, of more than two bones (the "astragalus" and "calcaneum"), the intermediate tarsal being lost by fusion with one of the others. The proximal and distal rows of tarsals are separated on the inner side of the foot by the "scaphoid" or "navicular" bone, probably representing the "os centrale"; and there are never more than four tarsals (the internal, middle, and external "cuneiform" bones, and the "cuboid") in the distal row.

The hind-foot, or *pes*, consists normally of five digits connected with the distal tarsal bones by means of five metatarsal bones. Very commonly, the number of the metatarsals and digits is reduced below the normal standard, and in such cases the reduction very generally takes place in a manner corresponding to that which obtains in the manus. The digit which is most commonly suppressed is the innermost or "great toe" (*hallux*), and this digit is wanting in all existing types of the Ungulate Mammals. Though the number of digits in the pes is very commonly the same as that in the manus, this is by no means invariably the case. The hallux is not uncommonly (*e.g.*, in the *Primates* generally) "opposable" to the other digits, so that the pes can be used as a prehensile hand.

In the *Mammalia* generally the bones of the *skull* are united to one another by distinct sutures. In the Monotremes (Duck-mole and Echidna), however, the cranial bones early become anchylosed with one another, as is the case in Birds. The occipital bone carries two condyles for articulation with the first cervical vertebra. Very generally, also, the exoccipitals carry longer or shorter, downwardly-projecting bony processes ("paroccipital processes"). The two rami of the mandible are generally united with one another by suture; but in some cases complete anchylosis takes place. The mandibular ramus is always composed of a single bone, and it articulates directly with the squamosal element of the skull, or, in other words, with the squamous portion of the temporal bone. The quadrate bone never takes any part in the articulation of the mandible, but is withdrawn within the auditory capsule, and constitutes the "malleus," while another of the auditory ossicles (the "incus") corresponds with the "hyomandibular bone" of Fishes and the "columella auris" of Reptiles.

Teeth are present in the great majority of Mammals; but they are only present in the embryo of the whalebone Whales, and are entirely absent in the genera *Echidna*, *Manis*, and *Myrmecophaga*. In the Duck-mole (*Ornithorhynchus*) the so-called teeth are horny, and the same was the case in the extinct *Rhytina* amongst the *Sirenia*. In all other Mammals the teeth have their ordinary structure of dentine, enamel, and cement or crusta petrosa, these elements being variously disposed in different cases, and the enamel being occasionally wanting. In no Mammals are the teeth ever anchylosed with the jaw; and in all, the teeth are implanted into distinct sockets or alveoli, which, however, are very imperfect in some of the *Cetacea*. In no Mammals, further, are teeth ever developed in any other bones except the præmaxillæ, maxillæ, and mandible.

Many Mammals have only a single set of teeth throughout life, and these are termed by Owen "monophyodont." In most cases, however, the first set of teeth—called the "milk" or "deciduous" teeth—is replaced in the course of growth by a second set of "permanent" teeth. The deciduous and permanent sets of teeth do not necessarily correspond to one another; but no Mammal has ever *more* than these two sets. The Mammals with two sets of teeth are called by Owen "diphyodont."

In Man and many other Mammals the teeth are divisible into four distinct groups, which differ from one another in position, appearance, and function; and which are known respectively as the *incisors*, *canines*, *præmolars*, and *molars* (fig. 439). "Those teeth which are implanted in the præmaxillary bones, and in the corresponding part of the lower jaw, are called 'incisors,' whatever be their shape or size. The tooth in the maxillary bone which is situated at or near to the suture with the præmaxillary, is the 'canine,' as is also that tooth in the lower jaw which, in opposing it, passes in front of its crown when the mouth is closed. The other teeth

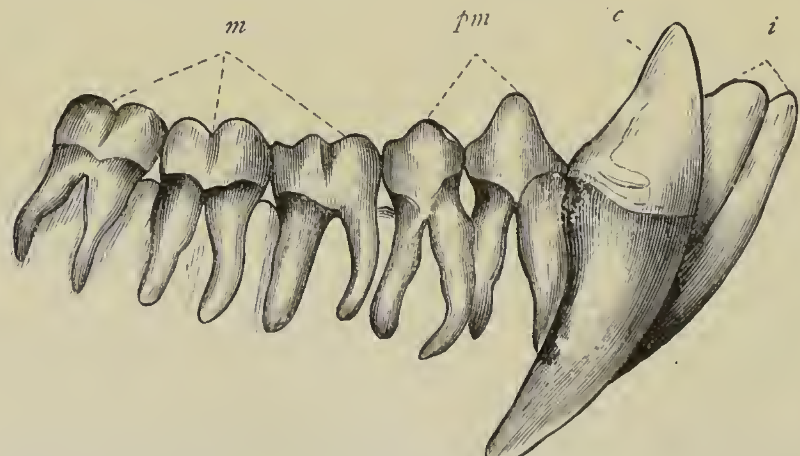


Fig. 439.—Teeth of the right side of the lower jaw of the Chimpanzee—(after Owen). *i* Incisors; *c* Canine tooth; *pm* Præmolars; *m* Molars.

of the first set are the 'deciduous molars'; the teeth which displace and succeed them vertically are the 'præmolars'; the more posterior teeth, which are not displaced by vertical successors, are the 'molars' properly so called" (Owen). The deciduous dentition, therefore, of a diphyodont Mammal consists of only three kinds of teeth—incisors, canines, and molars. The incisor and canine teeth of the deciduous set

are replaced by the teeth which bear the same names in the permanent set. The deciduous "molars," however, are replaced by the permanent "præmolars," and the "molars" of the permanent set of teeth are not represented in the deciduous series, only existing once, and not being replaced by successors. It has, however, been shown that in some diphyodont Mammals there may be certain of the anterior maxillary teeth in the permanent dentition, which are not represented by any predecessors in the deciduous series. This is the case, for example, with the first præmolar of the Dog.

All these four kinds of teeth are not necessarily present in all Mammals, and, as will be afterwards seen, the characters of the teeth are amongst the most important of the distinctions by which the Mammalian orders are separated from one another. The variations which exist in the number of teeth in different Mammals are usually expressed by a "dental formula," which presents the "dentition" of both jaws in a condensed and easily recognised form.

According to Owen, the typical permanent dentition of a diphyodont Mammal would be expressed by the following formula:—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{4-4}{4-4};\ m\,\frac{3-3}{3-3} = 44.$$

The four kinds of teeth are indicated in such a formula by the letters—incisors *i*, canines *c*, præmolars *pm*, molars *m*. The numbers in the upper line indicate the teeth in the upper jaw; those in the lower line stand for those in the lower jaw; and the number of teeth on each side of the jaw is indicated by the short dashes between the figures.

As regards the *digestive system* of the *Mammalia*, salivary glands are present in all except the true *Cetacea*. The alimentary canal has in most cases essentially the same structure as in man; and the same accessory glands are present—namely, the liver and pancreas. Some very remarkable modifications occur in the structure of the stomach and in the termination of the intestine; but these will be noticed in speaking of the orders in which they occur. The cavity of the abdomen is always separated from that of the thorax by a complete muscular partition—the diaphragm—as is the case in no other Vertebrate animals. The abdomen contains the greater portion of the alimentary canal, the liver, spleen, pancreas, kidneys, and other organs. The thorax mainly holds the heart and lungs.

The *heart* is contained in a serous bag, the pericardium,

and consists (as in Birds) of two auricles and two ventricles. The effete and deoxygenated blood is returned from the tissues by the veins, and is conducted by the venæ cavæ to the right side of the heart, into the right auricle. From the right auricle it passes into the right ventricle, whence it is propelled through the pulmonary artery to the lungs. Having been submitted to the action of the air, the blood, now arterialised, is carried by the pulmonary veins to the left auricle, and thence into the left ventricle. From the left ventricle the aerated blood is driven through the aorta and systemic vessels to all parts of the body. In Mammals, therefore, as in Birds, the pulmonary and systemic circulations are altogether distinct and separate from one another. The two sides of the heart—except in the fœtus and as an abnormality in adults—have no communication with one another except by means of the capillaries.

The red blood-corpuscles are never nucleated, and in all except the *Camelidæ* (in which they are oval) they are circular and discoid.

The *lungs* of Mammals differ from those of Birds in being freely suspended in the thoracic cavity, the greater part of which they fill, and in being enclosed freely in a serous sac (*pleura*) which envelops each lung. The lungs are minutely cellular throughout, and the bronchi never open on the surface of the lung into a series of air-receptacles communicating with one another, and placed in different parts of the body, as is the case in Birds.

There is no "inferior larynx" in any Mammal, and the upper aperture of the true larynx is always protected by an epiglottis.

The *kidneys* in Mammals are situated in the lumbar region, and exhibit a division of their substance into cortical and medullary portions.

The *nervous system* of Mammals is chiefly remarkable for the great proportionate development of the cerebral mass as compared with the size of the spinal cord. In the higher Mammals, again, the hemispheres of the cerebrum are much more largely developed proportionately than the remaining parts of the brain. The brain of the Mammals is chiefly distinguished from that of the lower *Vertebrata* by the fact that the two hemispheres of the cerebellum are united by a transverse commissure—the *pons Varolii;* and the hemispheres of the cerebrum are connected by a great commissure—the *corpus callosum*—which is, however, of small size in the lower *Mammalia*.

The senses, as a rule, attain great perfection in the Mammals; and the only sense which appears to be ever entirely wanting is that of vision. The sclerotic coat of the eye is never supported by a ring of bony plates as in Birds and many Reptiles. As a rule, in addition to the upper and lower eyelids there is a third perpendicular lid—the *membrana nictitans*—but this is wanting or quite rudimentary in Man and in the Monkeys.

An external ear or *concha* for collecting the vibrations of sound is usually present, but is wanting in the *Cetacea*, many of the Seals, and in some other cases.

As regards the *reproductive organs*, there are two ovaries in the female, and the oviducts are known as the "Fallopian tubes." The oviducts are not directly continuous with the ovaries, and, except in Monotremes, their internal extremities are widely dilated and fimbriated. On its way to the surface each oviduct dilates into a uterine cavity, which in turn opens into a vaginal tube. In the Monotremes, or "Ornithodelphous" Mammals, the uterine dilatations of the oviducts

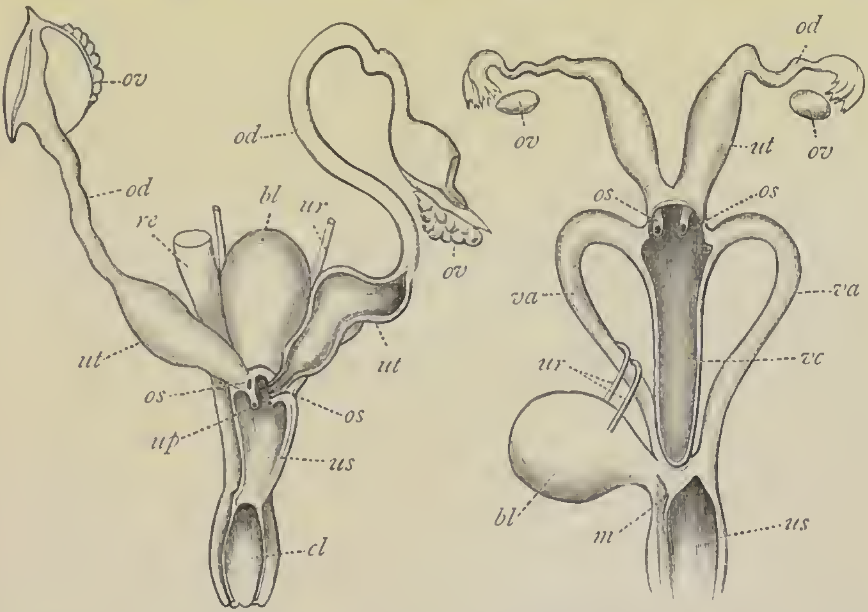


Fig. 440.—A, Generative organs of the female *Ornithorhynchus*, (after Owen). B, Female generative organs of a Kangaroo (*Halmaturus*), after Gegenbaur. *ov* Ovary; *od* Oviduct; *ut* Uterus; *os* Os uteri, or opening of the uterus; *ur* Ureter; *bl* Bladder; *up* Opening of the ureter; *us* Urogenital sinus; *va* Vagina; *vc* Cæcal diverticulum of vagina; *re* Rectum; *cl* Cloaca.

(fig. 440, A, *ut*) not only remain permanently separate, but they open separately into a common chamber or "urogenital sinus" (fig. 440, A, *us*), into which the ureters also open

The urogenital sinus, in turn, opens into a "cloaca," into which the intestine also opens. In the Marsupials, again, or "Didelphous" Mammals, the two uteri remain distinct (fig. 440, B, *ut*), and they open into two vaginæ (*va*) which are united mesially above and give off a long cæcal diverticulum (*vc*), but are separate inferiorly. The two vaginæ open into a "urogenital sinus" (*us*), into which the bladder also empties itself. On the other hand, the urogenital canal in the Marsupials opens separately from the intestine, and there is no cloaca. In the ordinary or "Monodelphous" Mammals, again, the two uterine dilatations of the oviducts coalesce with one another inferiorly, and the vagina is single. In most cases this coalescence is incomplete, the uteri being combined in their lower portion only, and separating above into two horns or "cornua," which mark their original separateness. Only in the higher Monkeys and in the human subject have the two uteri entirely coalesced to form a completely single cavity, into the "fundus" of which the Fallopian tubes open. In male Mammals there are always two testes present. In many Mammals the testes are permanently retained in the abdominal cavity, and there is no scrotum. This is the case in the Monotremes, the Elephants, all the *Cetacea*, and many of the *Edentata*. Mostly, however, the testes at an early period of life are transferred from the abdomen to a pouch of integument called the "scrotum." Usually the scrotum is placed beneath the pubic arch and behind the penis, but this position is reversed in the Marsupials.

Mammary glands are present in all Mammals, and they are regarded by Huxley as an extreme modification of the cutaneous sebaceous glands. In the male Mammals the mammary glands are present, but, under all ordinary circumstances, they remain functionally useless and undeveloped. Considerable differences obtain as to the number and position of the mammary glands in different cases; but they are always placed on the inferior surface of the body, and their ducts in the great majority of cases open collectively upon a common elevation —the "teat" or "nipple." In the *Monotremata*, however, there are no nipples, the ducts of the mammary glands opening either into a pouch of the integument (*Echidna*) or upon a flat surface (*Ornithorhynchus*).

The young Mammal is nourished for a longer or shorter time by the milk secreted by the mammary glands of the mother. In ordinary cases the milk is obtained by voluntary suction on the part of the young animal; but in the Marsupials the young are at first unable to suck for themselves, and the

milk is forced out of the gland by the contraction of a special muscle.

The Monotremes (Duck-mole and Echidna) are now known to be an exception to the Mammals generally in the fact that they do not bring forth their young alive, but are, on the contrary, oviparous. All the other Mammals produce living young, and are thus viviparous. The Marsupials, however, bring forth their young in an extremely imperfect condition, at a time when development has proceeded to a limited extent only, and in these the fœtus does not become connected with the uterus of the mother by any vascular connection ("placenta"). Hence the Marsupials are spoken of as "Aplacental" Mammals. In the other orders of Mammals, there is developed the structure known as the "placenta" or "afterbirth," this being a highly vascular structure which is formed upon the exterior of the fœtal envelopes (allantois), and which is so closely connected with the inner wall of the uterus as to allow of an interchange of material between the blood of the embryo and that of the mother. The "Placental" Mammals are thus enabled to carry their young for a much longer period than are the non-placental Mammals, and hence the young animal in the former is born in a much more perfectly-developed condition than in the latter.

As regards their *distribution in time*, the earliest known remains of Mammals are found in the Trias, rocks of this age having yielded remains of three genera of small Mammals (*Microlestes*, *Hypsiprymnopsis*, and *Dromatherium*), which are generally believed to belong to the Marsupials. In the Jurassic rocks, fragmentary remains of various small Mammals (*Amphilestes*, *Amphitherium*, *Phascolotherium*, *Plagiaulax*, &c.) have been discovered. These are also generally believed to be referable to the Marsupials, though one of the Jurassic genera (*Stereognathus*) has been supposed to possibly belong to the series of the Placental Mammals. Apart from the preceding, remains of undoubted Marsupials (Opossums) have been detected in the Jurassic deposits of North America. No Cretaceous Mammals are known at present; but a large number of forms have been found in the Tertiary rocks, from the base of the Eocene onward, and many of these have a special zoological interest as serving to indicate the line of descent of existing types, or filling gaps between groups now more or less widely separated.

As regards their *classification*, the Mammals have often been divided into the two primary sections of the *Placentalia* and *Aplacentalia*, according as the young are provided with a

"placenta" or not. The Non-placental Mammals are the Monotremes and Marsupials; and all the other orders of Mammals are included in the division *Placentalia.* The other method of arrangement usually adopted is to employ the structure of the reproductive organs as the basis of classification, and to divide the Mammals into the three following primary sections:—

1. *Ornithodelphia.*—This division includes only the Monotremes, and is characterised by the fact that the two uterine dilatations of the oviducts do not coalesce, but open separately into a urogenital sinus, which in turn opens, along with the rectum, into a "cloaca," the condition of parts thus resembling what is seen in the *Sauropsida.*

2. *Didelphia.*—This division includes only the Marsupials, and is characterised by the fact that the two uteri remain distinct, and open into a divided vagina, the vaginæ opening into a urogenital sinus, which is provided with a special external aperture, separate from the termination of the intestine though embraced by the same sphincter muscle.

3. *Monodelphia.*—This division comprises all the orders of Mammals except the Monotremes and Marsupials, and is characterised by the fact that the two uterine enlargements of the oviducts coalesce to a greater or less extent to form a single uterine cavity, which, however, commonly shows its true composition by being divided superiorly into two cornua. The uterus opens into a single vagina, which is always distinct from the rectum. This division corresponds with that of the "Placental" Mammals.

NON-PLACENTAL MAMMALS.

CHAPTER LXIV.

MONOTREMATA AND MARSUPIALIA.

ORDER I. MONOTREMATA.—The first and lowest order of the *Mammalia* is that of the *Monotremata*, constituting by itself the division *Ornithodelphia*, and containing only two types, both belonging to the Australian province—namely, the Duck-mole (*Ornithorhynchus*) and the Spiny Ant-eaters (*Echidna*).

The order is distinguished by the following characters:—*The intestine opens into a "cloaca," which receives also the products of the urinary and generative organs, which discharge themselves through a common urogenital canal. The mammary glands are without nipples: and the young are produced as eggs, the parent thus being oviparous. The pectoral arch has the coracoid bone distinct, and an interclavicle is present. The pelvis is furnished with marsupial bones. Teeth are wanting, or are represented by horny plates.*

The Monotremes are remarkable for the possession of characters which indicate relationships with the *Sauropsida* generally, and with the Birds in particular. The cranial bones of the Monotremes anchylose with one another in the adult, so that the sutures are early obliterated, as is the case with the skull of Birds. The sutures between the neural arches and the bodies of the vertebræ are persistent (as in many Reptiles), and the cervical vertebræ carry short ribs, which remain long distinct. The coracoid bones, as in no other Mammals, remain separate from the scapula, and are large enough to articulate with the sternum. A large T-shaped interclavicle (fig. 441, *i*) is present, and fixed to its anterior edge are the slender clavicles (*c c*). There are sternal ribs (fig. 441, *sr*), separated from the vertebral ribs by short intermediate pieces. The acetabulum is perforated, as in Birds, and the brim of the

pelvis is provided with "marsupial bones." The jaws are elongated, and are either toothless (*Echidna*), or carry two pairs of horny plates which act as teeth (*Ornithorhynchus*). The feet are

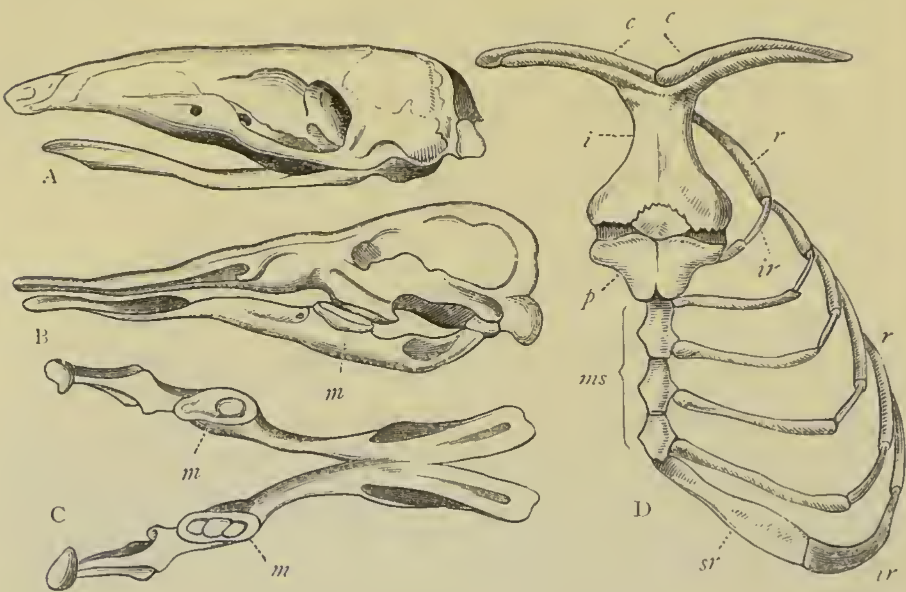


Fig. 441.—Osteology of Monotremes. A, Skull of *Echidna hystrix*. B, Side view of the skull of *Ornithorhynchus anatinus*; and C, Lower jaw of the same, viewed from above, showing the horny dental plates (*m*). D, Sternum and adjacent parts of the skeleton of a young *Ornithorhynchus*: *c c* Clavicles; *i* Interclavicle; *p* Præsternum; *ms* Mesosternum; *r r* Vertebral ribs; *ir* Intermediate ribs; *sr* Sternal ribs. (A, B, and C are after Giebel; D is after Flower.)

five-toed, some or all of the toes being clawed; and the males carry perforated spurs on the back of the tarsus, connected with the duct of a gland, and probably having a sexual function.

Of their other characters, the most remarkable are those relating to the condition of the reproductive organs, and the mode of development of the young. As has been previously seen (p. 729, fig. 440), the uterine dilatations of the oviducts remain in the Monotremes separate from one another, and open separately into a urogenital sinus. This sinus receives also the terminations of the ureters, which open separately from the bladder, and it opens into a "cloaca," into which the rectum also discharges itself. In the males, the vasa deferentia similarly open into a urogenital sinus which, in turn, opens into the cloaca. The condition of parts in the Monotremes, so far as the reproductive and urinary organs are concerned, is thus very similar to that which obtains in Birds.

Through the researches of Caldwell — as yet but incompletely published — it is now known that the Monotremes

further resemble the *Sauropsida*, and differ from the *Mammalia* generally, in being *oviparous*. The *Ornithorhynchus* produces two eggs, enclosed in a flexible shell, at a birth, and the *Echidna* lays one such egg. The eggs, moreover, are like those of Birds, in being of comparatively large size, and containing much food-yolk. As in the case of Birds, therefore, the ovum is "meroblastic," or, in other words, undergoes but partial segmentation.

The mammary glands have no nipples, and open on the surface in a different manner in the two genera of Monotremes. In the *Ornithorhynchus*, the ducts of the mammary glands

Fig. 442.—Monotremata. *Ornithorhynchus anatinus*, Australia.

open on a slightly depressed space, and there is nothing in the way of a "marsupial pouch." In the *Echidna*, on the other hand, each of the two mammary glands opens into a kind of mammary pouch, at the bottom of which the ducts of the glands discharge themselves, there being no nipple. It would appear that the egg of the *Echidna* is placed, on being laid,

in one of these mammary pouches, within which it is hatched, the young animal subsequently receiving milk from the mammary glands in some manner not fully understood.

The order *Monotremata* includes only the two genera *Ornithorhynchus* and *Echidna* (or *Tachyglossus*)—the one represented by a single species (*O. paradoxus* or *anatinus*), and the other by four species (*E. hystrix*, *E. setosa*, *E. Lawesi*, and *E. Bruijnii*). All are exclusively confined to the Australian province.

The *Ornithorhynchus* or Duck-mole is one of the most extraordinary of Mammals. The body (fig. 442) resembles that of a mole or small otter, and is covered with a close, short, brown fur. The tail is broad and flattened. The jaws are produced to form a beak just like that of a duck in appearance; hence the name of "Duck-billed animal," often applied to it. The margins of the jaw are sheathed with horn, and are furnished with transverse horny plates, two in each jaw (fig. 441, B and C): but there are no true teeth. The sternum (fig. 441, D) is of five pieces, and there are sternal ribs. The nostrils are placed at the apex of the upper mandible. The legs are short, and the feet have five toes, each furnished with strong claws, which enable the animal to burrow with facility. The toes are also united by a membrane or web, so that the animal swims with great ease. The *Ornithorhynchus* is exclusively found in Australia, ranging as far north as Queensland, and in Tasmania, inhabiting streams and ponds. Its food consists chiefly, if not exclusively, of insects, and the animal makes very extensive burrows in the banks of the rivers which it frequents. The young when hatched are quite blind, and nearly naked, and the method in which they obtain milk from the mother is somewhat obscure, as there are no nipples, nor is there any marsupial pouch. It is certain, however, that the beak of the young animal is extremely different from what it is in the adult condition. The young animal is totally hairless, the mandibles are soft and flexible, the tongue is not placed far back in the mouth (as it is in the adult), and the eye is at first covered by the skin.

The genus *Echidna* (*Tachyglossus*) is represented by at least four species —viz., *E. hystrix*, *E. setosa*, *E. Lawesi*, and *E. Bruijnii*, the first being Australian, and the second Tasmanian, whilst the two last occur in New Guinea. The *Echidna hystrix* is the best-known species, and in some external respects is not unlike a large hedgehog, having the back covered with strong spines, interspersed with a general coating of bristly hairs. The snout has not the form of a duck's bill, as in the *Ornithorhynchus*, but the two jaws are greatly elongated, and are enclosed in a continuous skin till close upon their extremities, where there is a small aperture for the protrusion of a very long and flexible tongue. The jaws (fig. 441, A) are wholly devoid of teeth or anything in the place of teeth; and the nostrils are placed at the extremity of the cylindrical snout. The feet have five toes each, furnished with strong curved digging-claws, but the toes are not webbed. The *Echidna hystrix* measures from fifteen to eighteen inches in length, and is a nocturnal animal. It lives in burrows and feeds upon insects, which it catches by protruding its long and sticky tongue.

As regards the distribution of the *Monotremes* in *time*, no fossil remains referable to the genus *Ornithorhynchus* have

been as yet discovered; but fossil species of *Echidna* have been found in the Post-Pliocene deposits of Australia.

ORDER II. MARSUPIALIA.—The order *Marsupialia* constitutes by itself the sub-class *Didelphia*, and forms with the *Monotremata* the division of the Non-placental Mammals. With the exception of the genera *Didelphys* and *Chironectes*, which are American, all the *Marsupialia* belong to the Australian province; that is to say, they all belong to Australia, Van Diemen's Land, New Guinea, and some of the neighbouring islands.

The following are the characters which distinguish the order:—

The skull is composed of distinct cranial bones united by sutures, and the jaws are provided with true teeth. The angle of the lower jaw (except in one species of Phalanger), is bent inwards towards the middle line, or is "inflected" (fig. 443). *The pectoral arch has the same form as in the higher Mammals, the coracoid being fused with the scapula, and no longer reaching the top of the sternum. "Marsupial bones" or "marsupial cartilages" are attached to the brim of the pelvis. The uterine dilatations of the oviducts do not coalesce, but the external opening of the urogenital sinus is distinct from the termination of the intestine, and there is no "cloaca." The young are brought forth alive, but are not provided with a placenta. The mammary glands have nipples, and these are very long, and are usually contained within a "marsupium" or pouch-like fold of the skin of the abdomen. As is also the case in the Monotremes, the corpus callosum of the brain is very small.*

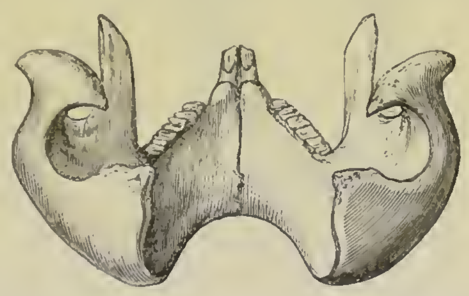


Fig. 443.—Lower jaw of the Wombat, viewed from behind, showing the strongly inflected angles of the jaw.

The skull of the Marsupials is in general readily recognised by the inflection of the angle of the lower jaw (fig. 443), a character present in all the members of the order with the exception of one species of Phalanger (the little *Tarsipes rostratus* of Western Australia). Another general character of the skull is that the incisors in each half of the lower jaw are either only one in number, or if they are three in number, then the corresponding incisors in the upper jaw are *more* than three in number. The presence of "marsupial bones" (fig. 444) is

not a conclusive test as to whether or not a skeleton is Marsupial, since these bones are found in the Monotremes also.

The most characteristic points with regard to the Marsupials are to be found in the mode of development of the young. In all the Marsupials, namely, the young are born in a very imperfect condition, of a very small size, and at a period when their development has proceeded to a very limited extent only. In the Great Kangaroo, the period of gestation is only thirty-nine days, and the embryo when born is hardly more than an inch in length. In the Opossums (*Didelphidæ*) the period of gestation is only from fifteen to seventeen days. Owing to the brevity of the period of gestation, no placenta is developed, and the entirely helpless young are at birth transferred by the mother to the nipples, which are of great length, and are usually contained within a pouch or "marsupium" formed by a folding of the skin of the abdomen. In some cases there is no regular "marsupium," but the structure of the nipples is in all cases the same, and the young are nourished in the same way. In all cases, namely, the young are carried about by the mother, adhering to the lengthy teats, and being for some time after birth extremely feeble, and unable to perform the act of suction, they are nourished involuntarily, the milk being forced into their mouths by the contraction of special muscles covering the mammary glands. Choking is obviated during this process by the upward prolongation of the windpipe to the posterior nares, the act of swallowing thus not interfering with respiration. At a later stage, the young can suckle by their own exertions, and when a pouch is present, they can leave it and return to it at will. That the "marsupial bones" have no special connection with the presence of a "marsupium" is shown by their occurrence in Monotremes, in which there is no pouch; but they are believed by Owen to serve as a fulcrum for the muscle spread over the mammary gland; and in the males they perform a similar office for the cremaster muscle.

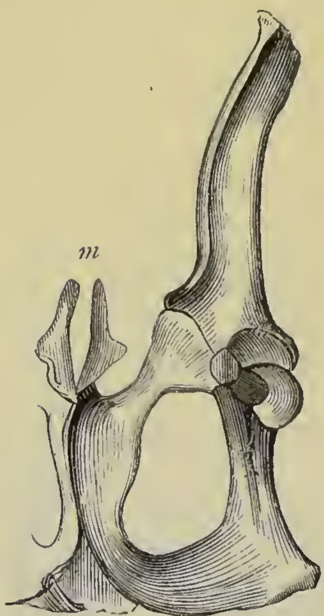


Fig. 444.—One side of the pelvis of a Kangaroo, showing the "marsupial bones" (*m*). (After Owen.)

The condition of the reproductive organs has been previously noticed (p. 729, fig. 440). The two uteri are completely distinct, and there are also two vaginæ, which have a short common portion at the point where the uteri open into them. At this point also is a long backwardly-directed vaginal cæcum. The two vaginæ open into a urogenital sinus, and the external aperture of this is separate from that of the intestine, though embraced by a sphincter muscle common to it and to the rectum. The testes are not abdominal throughout life, as they are in the Monotremes, but are lodged in a scrotum. This, however, is placed in front of the penis, and not beneath the pubic arch as it is in Mammals generally.

Though they constitute an extremely natural order, sharply separated from all the rest of the Mammals, the Marsupials form a large and varied group. In fact, this order, from being the almost exclusive possessor of a continent as large as Australia, has to discharge in the economy of nature functions which are elsewhere discharged by several orders.

The *Marsupialia* are divided by Owen into the two primary sections of the *Diprotodontia* and *Polyprotodontia*, comprising the following subordinate divisions:—

(A.) DIPROTODONTIA.—Lower incisors two in number; canines rudimentary or wanting; molars mostly with broad crushing crowns.

Sub-order I. Rhizophaga.—This sub-order includes only the

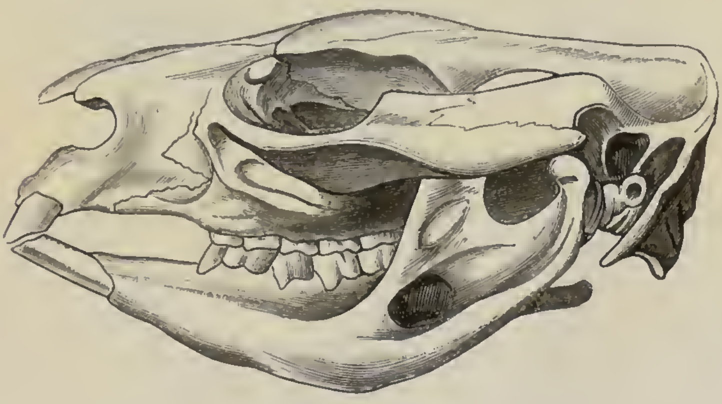


Fig 445.—Skull of Wombat. (After Giebel.)

single genus *Phascolomys*, comprising only the Wombat, and is characterised by the fact that there are only two upper and two lower incisors, and these have chisel-shaped crowns, and grow from permanent pulps.

The Wombat (*Phascolomys fossor*) is a stout, heavy animal, which attains a length of from two to three feet. The legs are very short and stout, and the animal burrows with ease by means of strong, curved digging-claws, with which the fore-feet are furnished. The tail in the Wombat is quite rudimentary, and the whole body is clothed with a brown woolly hair. In its dentition (fig. 445) the Wombat presents a curious resemblance to the herbivorous Rodents. There are two incisors in each jaw, and these are long and rootless, growing from permanent pulps. There are no canines, so that the incisors and præmolars are separated by a considerable space. The dental formula is—

$$i\,\frac{1-1}{1-1};\ c\,\frac{0-0}{0-0};\ pm\,\frac{1-1}{1-1};\ m\,\frac{4-4}{4-4}=24.$$

The præmolars and molars agree with the incisors in growing from permanent pulps, in which respect the Wombat differs from all the other Marsupials, and agrees with the herbivorous Rodents, with those *Edentata* which have teeth, and with the extinct *Toxodon* (Owen).

The Wombat is a nocturnal animal, and feeds chiefly upon roots and grass; it is found in both Australia and Van Diemen's Land.

Sub-order II. Poephaga.—This sub-order comprises the Kangaroos and Kangaroo-rats, which together constitute the family of the *Macropodidæ*. There are only two lower incisors (one on each side), and these are horizontal and chisel-shaped (fig. 446); and there are three upper incisors on each side.

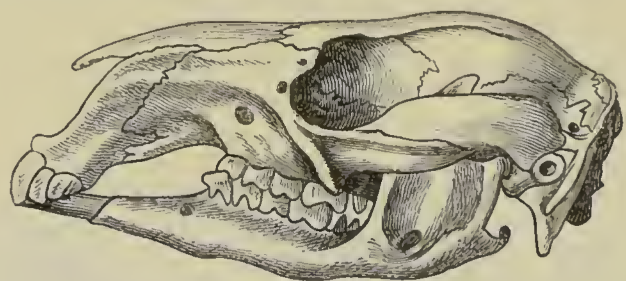


Fig. 446.—Skull of *Macropus Bennettii*. (After Giebel.)

There is a complete marsupium, in which the nipples (four in number) are contained.

The typical Kangaroos (*Macropus*) are strictly phytophagous, and are distinguished by the disproportionate length of the hind-limbs, and the disproportionate development of the posterior portion of the body as compared with the fore-limbs and fore-part of the body. The hind-legs are exceedingly long and strong, and the feet are much elongated—the whole sole being applied to the ground. The hind-feet (fig. 447) have four toes each, of which the central one (the 4th toe) is by far the largest, and the two inner toes (the 2d and 3d toes) are very small, and are united by a common integument. The hallux is wanting altogether. The tail is also extremely long and strong, and is of great assistance to the animal when standing upright upon the hind-limbs. From the length and strength of the hind-limbs and hind-feet, the Kangaroos are enabled to effect extra-

ordinarily long and continuous bounds. In fact, leaping is the ordinary mode of progression in the typical Kangaroos; and when walking upon all fours their locomotion is slow and ungraceful. The anterior extremity of the body is very diminutive as compared with the posterior, and the fore-limbs are quite small, but have five well-developed toes armed with strong nails. The head is small, with large ears, and the dental formula is—

$$i\,\frac{3-3}{1-1};\ c\,\frac{0-0}{0-0};\ pm\,\frac{1-1}{1-1};\ m\,\frac{4-4}{4-4} = 28.$$

There are therefore six upper incisors, two lower incisors (the latter horizontal, fig. 446), and no functional canines (though rudimentary upper canines are present in the young of some of the Kangaroos, at any rate). The stomach is complex, and sacculated. The Kangaroos are all herbivorous, and mostly live, either scattered or gregariously, on the great grassy plains of Australia. The "Tree-kangaroos," however (constituting the genus *Dendrolagus*), live mostly in trees; and in adaptation to this mode of life, the fore-legs are nearly as long and strong as the hind-legs, the tail is not used as a support, and the claws are long, curved and pointed, while small upper canines are present. They are natives of New Guinea. The "Rock-kangaroos" form the genus *Petrogale*, and inhabit the mountainous regions of North-western Australia.

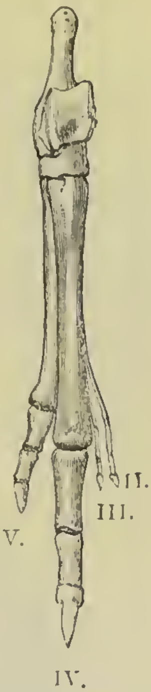


Fig. 447.—Hind-foot of *Macropus Bennettii*. (After Flower.)

The Kangaroo-rats (*Hypsiprymnus*) are small, somewhat rat-like animals, with hind-legs longer than the fore-legs, and with scaly tails. They differ in their dentition from the ordinary Kangaroos, as they have well-developed upper canines (fig. 448, *c*). In the adult there is only a single præmolar in each jaw, this being of large size, and marked on its sides with distinct vertical grooves. The extinct Jurassic genus

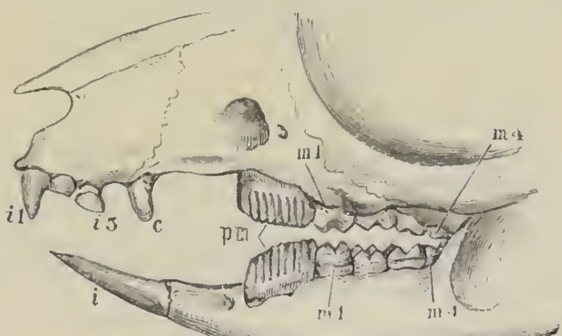


Fig. 448.—Dentition of the Kangaroo-rat (*Hypsiprymnus cuniculus*). *i* 1–*i* 3 Upper incisors; *i* Lower incisor; *c* Upper canine; *pm* Vertically-grooved præmolar; *m* 1–*m* 4 Molars.

Plagiaulax has similarly grooved præmolar teeth, but in this case the grooves are oblique. The Kangaroo-rats are diminutive nocturnal ani-

mals, and they feed mostly upon roots. They are found both in Australia and Tasmania.

Sub-order III. Carpophaga.—This sub-order includes the "Koala" (*Phascolarctos*), and the various small Marsupials which are usually known as "Phalangers" (*Phalangistidæ*). The members of this sub-order have three upper and one lower incisor on each side, and have small upper canines; while the second and third digits of the hind-feet are united by the skin.

The singular animal known by the Australian colonists as the "native Sloth" or "Bear," and by the natives as the "Koala" (*Phascolarctos cinereus*), represents a special group of this sub-order. It is about two feet in length, having a stout body, covered with a dense bluish-grey fur. The tail is wanting (fig. 449); and the feet are furnished with strong curved

Fig. 449.—"Koala" (*Phascolarctos cinereus*).

claws, which enable the animal to pass the greater part of its existence in trees. In this it is greatly assisted by the fact that all the feet are prehensile, the hallux being opposable, and the digits of the fore-limb divided into two sets, the thumb and index-finger being opposable to the other fingers. The dental formula is—

$$i\,\frac{3-3}{1-1};\quad c\,\frac{1-1}{0-0};\quad pm\,\frac{1-1}{1-1};\quad m\,\frac{4-4}{4-4} = 30.$$

The Koala is a slow animal which feeds on the foliage of the trees in which it spends its existence.

The typical group of the carpophagous Marsupials is that of the *Phalangistidæ* or Phalangers, so called because the second and third

digits of the hind-feet are joined together almost to their extremities. The family includes a number of small Marsupials, fitted for an arboreal existence, to which end the hallux is opposable and nail-less, whilst the four remaining toes of the hind-feet have long curved claws. The tail, too, is generally very long, and its tip is usually prehensile. The Phalangers are all small nocturnal animals which live upon fruits and other vegetable food. The best known of them is the Australian Opossum or Vulpine Phalanger (*Phalangista vulpina*), which must not be confounded with the true or American Opossums, which belong to another section of the *Marsupialia.* The Phalangers, namely, are distinguished from the Opossums properly so called, amongst other characters, by their dentition, the canine teeth being always very small and functionally useless in the lower jaw, and sometimes in the upper jaw as well. The *Phalangista vulpina* is nocturnal and arboreal in its habits, and its flesh is esteemed a great delicacy by the native Australians, with whom opossum-hunting is a favourite pursuit.

The flying Phalangers or *Petauri* are closely allied to the true Phalangers, but differ in not having a prehensile tail, and in having a fold of skin extending on each side between the sides of the body and the hind and fore limbs. By the help of these lateral membranes the *Petauri* can take extensive leaps from tree to tree ; but though called "flying" Phalangers, they have no power of flight properly so called. They are beautiful little animals, nocturnal in their habits, and having the body clothed with a soft and delicate fur.

The singular little Marsupial which alone constitutes the genus *Tarsipes* resembles the preceding forms in having only two lower incisors, and in having the second and third toes united by skin. It resembles the forms which follow, however, in having lower as well as upper canines. It is the only Marsupial in which the angle of the mandible is not inflected. It is a very diminutive animal, and is found in Western Australia.

(B.) POLYPROTODONTIA.—Lower incisors more than two in number ; canines more or less well developed ; molars cuspidate or with sectorial crowns.

Sub-order IV. Entomophaga.—This sub-order includes the families of the Bandicoots (*Peramelidæ*), the true Opossums (*Didelphidæ*), and the Banded Ant-eaters (*Myrmecobiidæ*). All

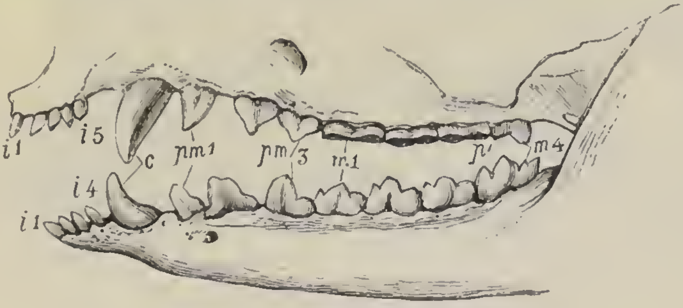


Fig. 450.—Dentition of Opossum (*Didelphys*).

the members of this section agree with the typical Carnivorous Marsupials in having both lower and upper canines, and in being adapted for an animal diet (fig. 450). The canines are,

however, of no large size, and the molars have cuspidate crowns. The members of this order are not, therefore, highly predaceous, but "prey, for the most part, on the smaller and weaker classes of Invertebrate animals" (Owen).

The Bandicoots (*Peramelidæ*) are small Australian animals, which appear to fill the place of the Hedgehogs, Shrew-mice, and other small *Insectivora* of the Old World. The molars are cuspidate, and canines are present. The dental formula is—

$$i\,\frac{5-5}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{3-3};\ m\,\frac{4-4}{4-4} = 48.$$

The hind-limbs in the Bandicoots are considerably longer than the fore-limbs, and their progression is therefore by a series of bounds. The fore-limbs have really five toes each, but only the central three of these are well developed, the outermost and innermost digits being rudimentary. The three functional toes are armed with long and strong claws, with which the Bandicoots burrow with great ease. The marsupial pouch—and this is a singular point—opens backwards instead of forwards. In the nearly-allied genus *Chœropus*, also from Australia, the fore-foot has only two functional digits (the 2d and 3d), the 1st and 5th digits being wanting, and the 4th being rudimentary; while the 4th digit of the hind-foot is the only functional toe.

The second family of this section—namely, that of the true Opossums or *Didelphidæ*—is remarkable in being the only group of the whole order which

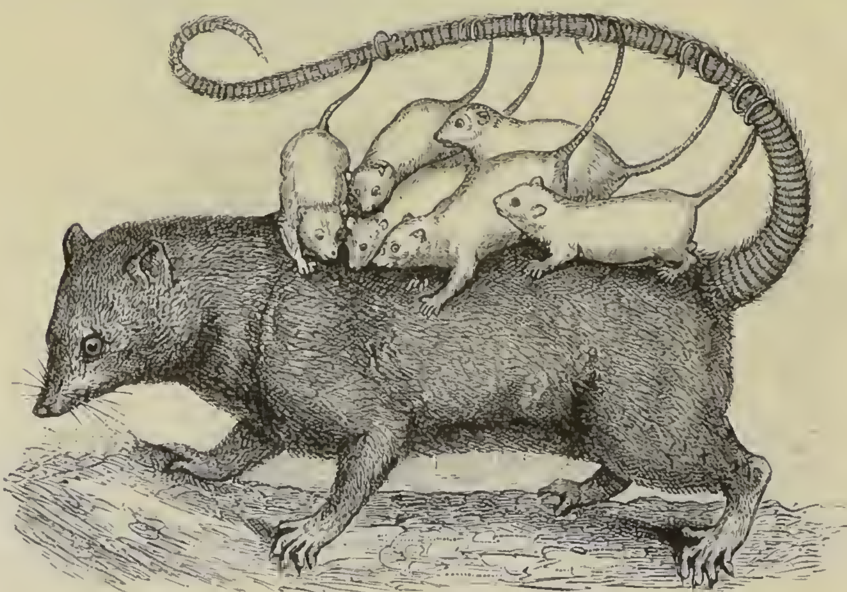


Fig. 451.—The female of *Didelphys dorsigera*, one of the South American Opossums, carrying its young upon its back.

occurs out of the Australian province. The *Didelphidæ*, namely, are exclusively found in North and South America, where they are known as "Opossums." A considerable number of species is known, but they are mostly of small size, the largest measuring not more than from two to

three feet, inclusive of the tail. The Virginian Opossum (*Didelphys virginiana*) is the only member of the family which is found in north of Mexico, and it was the earliest Marsupial known to science; its place in South America is taken by the widely-distributed *Didelphys d'Azaræ*. Most of the Opossums are carnivorous, feeding upon small quadrupeds and birds, but they also eat insects, and sometimes even fruit. One species (*Didelphys cancrivora*) lives chiefly upon Crabs; and the Yapock (*Cheironectes*) has webbed feet, and leads a semi-aquatic life. All the *Didelphidæ* have the hallux nail-less and opposable to the other toes, so as to convert the hind-feet into prehensile hands, and all have a more or less perfectly prehensile tail, these being adaptations to an arboreal life. The marsupial pouch is sometimes not present in a complete form, but is merely represented by cutaneous folds of the abdomen concealing the nipples. In the *Didelphys dorsigera* (fig. 451), in which this peculiarity obtains, the young soon leave the nipples, and are then carried about on the back of the mother, to whom they cling by twining their prehensile tails round hers. The dentition of the Opossums (fig. 450) is remarkable for the great number of the incisor teeth, the dental formula being—

$$i\,\frac{5-5}{4-4};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{3-3};\ m\,\frac{4-4}{4-4} = 50.$$

The canines are well developed, and the crowns of the molars are cuspidate.

The Banded Ant-eater (*Myrmecobius fasciatus*), which alone constitutes the family of the *Myrmecobiidæ*, is a small but extremely elegant little animal, which inhabits Western and Southern Australia, and lives upon insects. The tail is bushy, and differs from that of the *Didelphidæ* in not being prehensile. The fore-feet have five toes armed with claws; the hind-feet have only four toes. The *Myrmecobius* is remarkable for the extraordinary number of molar teeth, in which it exceeds any existing Marsupial, and is only surpassed by some of the Armadillos. The dental formula is—

$$i\,\frac{4-4}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{3-3};\ m\,\frac{6-6}{6-6} = 54.$$

Sub-order V. Sarcophaga.—This section comprises the family of the *Dasyuridæ*, including a number of carnivorous Mar-

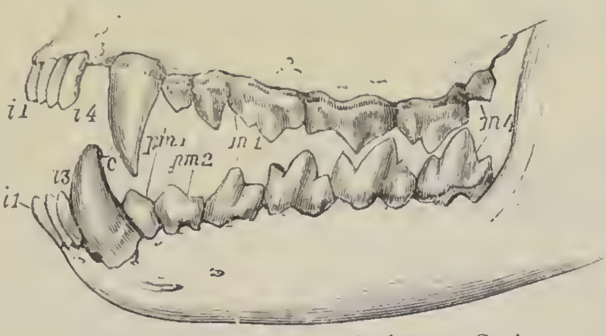


Fig. 452.—Dentition of *Dasyurus ursinus*. *i* Incisors; *c* Canines; *pm* Præmolars; *m* Molars.

supials, which resemble the typical *Carnivora* in being organised for preying upon other animals. They have no cæcum to

the intestine, and the dentition (fig. 452) is highly carnivorous, the canines being long and pointed, and the molar and præmolar teeth having cutting edges furnished with three cusps. There are three lower and four upper incisors on each side, the incisors thus differing from those of the true *Carnivora*, in which there may be *fewer* but are never *more* than three incisors on each side of each jaw.

The *Dasyuridæ*, or "Native Cats," are widely distributed over the Australian region, and are represented by many species, of which one of the best known is the "Native Devil" (*Dasyurus ursinus*) of Tasmania. This species is about as large as a Badger, and is of a ferocious and untamable disposition. Its dental formula is—

$$i\ \frac{4-4}{3-3};\ c\ \frac{1-1}{1-1};\ pm\ \frac{2-2}{2-2};\ m\ \frac{4-4}{4-4} = 42.$$

All the præmolars and molars (fig. 452) have cutting edges. There are various other species of *Dasyurus*, mostly of small size, which inhabit both Australia and Tasmania.

The genus *Thylacinus* includes the dog-like "Thylacine" (*T. cynocephalus*), which is a native of Tasmania, the inhabitants of which know it under the name of the "hyæna," its banded body giving it somewhat the appearance of this latter animal. The Thylacine is not unlike a Wolf in general aspect, and it grows to the size of a sheep-dog. The muzzle is long, and the general aspect of the skull is very like that of a Fox. The "marsupial bones" are represented in the Thylacine by cartilages only, and the marsupial pouch opens backwards.

Of the other genera of *Dasyuridæ*, one of the best known is *Phascogale*, comprising a number of weasel-like, arboreal Marsupials, which inhabit Australia, Van Diemen's Land, and New Guinea.

As regards their *distribution in time*, it is probable that the fragmentary remains of Mammals which have been found in the Trias, and which constitute at present the earliest evidence of the existence of Mammals upon the earth, are referable to the Marsupials. Upon these remains have been founded the genera *Dromatherium* (fig. 453), *Microlestes* (fig. 454), and *Hypsi-*

Fig. 453.—Lower jaw of *Dromatherium sylvestre*. Trias, North Carolina. (After Emmons.)

a *b*

Fig. 454.—*a* Molar tooth of *Microlestes antiquus*, magnified; *b* Crown of the same, magnified still further. Trias, Germany.

prymnopsis; but as these are only known from the detached ramus of the mandible, or from separate teeth, it is not possible to determine their affinities with certainty.

In the Jurassic rocks a number of forms of Mammals have been discovered, and upon these have been founded various genera (*Amphitherium*, *Phascolotherium*, *Plagiaulax*, *Triconodon*, &c.). Such remains of these as have been found indicate the existence of a number of small Mammals, which have usually been regarded as related to such existing Marsupials as *Myrmecobius*, or to the Kangaroo-rats. In none of these extinct forms is more known of the skeleton than the detached ramus of the mandible, and their affinities are therefore uncertain. In one of them, however—viz., *Plagiaulax* (fig. 455)—the resemblance of the grooved præmolar teeth to the great

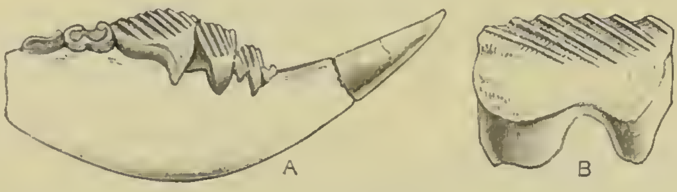


Fig. 455.—A, Right ramus of the lower jaw of *Plagiaulax minor*—Jurassic, enlarged four diameters. B, Third præmolar of *Plagiaulax Becklesii*, enlarged five and a half times, showing the diagonal grooves on the exterior of the crown. (After Owen.)

grooved præmolar of the recent Kangaroo-rats (fig. 448) is close enough to warrant a confident belief that this genus is really Marsupial. In the Jurassic rocks of the United States, moreover, Marsh has obtained the remains of Opossums (*Dryolestes*) which appear to belong to the characteristic American group of the *Didelphidæ*. As regards the Tertiary series, it is interesting to note that the Opossums, now wholly confined to the New World, had in early Tertiary times representatives in Europe (the genus *Peratherium*).

In the Post-Tertiary deposits of Australia have been found the remains of a large number of extinct Marsupials, which represent the now existing groups, but were for the most part of comparatively gigantic dimensions. Thus we meet with the remains of Wombats, Phalangers, Kangaroos, and carnivorous Marsupials like the living Dasyure and Thylacine. Of the Kangaroo-like forms one of the most remarkable is the genus *Diprotodon*, the species of which were of comparatively gigantic size. Others of the extinct Australian Marsupials, such as *Thylacoleo*, differ in important respects from any of the types now in existence.

PLACENTAL MAMMALS.

CHAPTER LXV.

EDENTATA.

ORDER III. EDENTATA or BRUTA.—The lowest order of the placental or monodelphous Mammals is that of the *Edentata*, often known by the name of *Bruta*. The name *Edentata* is certainly not an altogether appropriate one, since it is only in two genera in the order that there are absolutely no teeth. The remaining members of the order have teeth, but these are *always destitute of true enamel, are never displaced by a second set, and have no complete roots. Further, in none of the Edentata are there any median incisors, and in only one species (one of the Armadillos) are there any incisor teeth at all. Canine teeth, too, are almost invariably wanting. Clavicles are usually present, but are absent in the Scaly Ant-eaters (Manis). All the toes are furnished with long and powerful claws.* The mammary glands are usually pectoral, but are sometimes abdominal in position. The testes are abdominal in position. *The skin is often covered with bony plates or horny scales.*

The placentation of the Edentates varies, the placenta being discoidal and deciduate in the Sloths (*e.g.*, *Cholæpus Hoffmanni*), but diffuse and non-deciduate in *Manis* (Turner) —a fact which throws some doubt on the propriety of using the placental characters in classification.

The order *Edentata* is conveniently divided into two great sections, in accordance with the nature of the food, the one section being phytophagous, the other insectivorous. In the former section is the single group of the Sloths (*Bradypodidæ*). In the latter are the two groups of the Armadillos (*Dasypodidæ*), and the various species of Ant-eaters (the latter constituting Owen's group of the *Edentula*).

The order *Edentata* is but sparingly represented in modern

times, and its geographical distribution is peculiar. The true Ant-eaters, the Armadillos, and the Sloths, are entirely confined to South America, in which country a group of gigantic extinct Edentates existed in Post-tertiary times. The Scaly Ant-eaters (*Manis*) are common to Asia and Africa, and the genus *Orycteropus* is peculiar to Africa.

The following are the families of the existing *Edentata* :—

1. *Bradypodidæ* (or *Tardigrada*).—This family includes only the singular South American animals known as the Sloths, characterised by being arboreal and plant-feeding Edentates, with the fore-limbs longer than the hind-limbs, and the tail

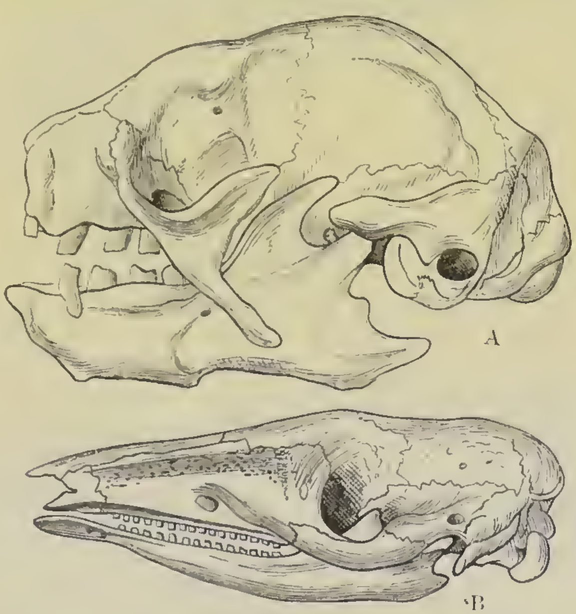


Fig. 456.—A, Side view of the skull of *Bradypus cuculliger;* B, Side view of the skull of *Dasypus gigas.* (After Giebel.)

rudimentary or absent. The are no incisor teeth (fig. 456, A), but there are $\frac{5-5}{4-4}$ or $\frac{5-5}{5-5}$ rootless molars, which grow from permanent pulps, and have the form of simple cylinders of dentine enveloped in cement. The ribs are very numerous, varying from fifteen to seventeen pairs in *Bradypus*, but being as many as twenty-three or twenty-four pairs in *Cholœpus*. The malar bone (fig. 456, A) is not directly articulated with the temporal, and sends backwards two long processes, one directed upwards and one downwards. The stomach is complex, somewhat resembling that of the Ruminants. The long bones have no medullary cavities.

The Sloths have a remarkably short and rounded face, and the body is covered with coarse harsh hair. The mammary glands are two in number, and pectoral in position. Living as they do in the vast primeval forests of South America, the Sloths are adapted for a purely arboreal mode of life, being constructed to pass their existence suspended back downwards from the branches of trees. They not only thus move freely, but even in sleep they retain this apparently unnatural position. To fit them for this mode of life the fore-limbs are much longer than the hind-limbs, and the bones of the fore-arm are unusually movable. All the feet, but especially the fore-feet, are furnished with enormously long curved claws (fig. 457), and

Fig. 457.—Hand of Three-toed Sloth (*Bradypus tridactylus*). (After Owen.)

the ungual phalanges are so articulated that the claws are bent inwards towards the hand or sole. The toes themselves are rigid, and are so enveloped in the integument as to leave nothing visible except the long and crooked claws. The feet are thus admirably adapted for the peculiar mode of climbing practised by the Sloths. Owing, however, to the fact that the hand and foot are jointed to the arm and leg obliquely, the palm and sole are turned inwards, and cannot be applied to the ground. Hence terrestrial progression can only be slowly and painfully effected by the Sloths.

In the genus *Bradypus* are the so-called Three-toed Sloths, in which the fore-feet have three toes each. Nine cervical vertebræ are present. The best-known species is the Aï (*Bradypus tridactylus*). In the genus *Cholœpus* there are only two toes to the fore-feet; and the first teeth in each jaw are longer and more pointed than the others, and have been regarded as canines. In the Unau (*C. Hoffmanni*) there are only six cervical vertebræ; but in *Cholœpus didactylus* the neck vertebræ have their normal number.

2. *Myrmecophagidæ.*—This family includes the Hairy Ant-eaters of South America, and is characterised by the fact that the jaws are toothless, the tongue is long and protrusible, and the salivary glands are exceptionally developed. The skin is covered with hair, and the feet are armed with long curved claws, adapted for digging or climbing. The malar (jugal) does not reach the temporal bone, but has no descending process.

The best-known member of this family is the Great Ant-eater (*Myrmecophaga jubata*). This singular animal attains a length of over four feet, and has an extremely long and bushy tail. The jaws are produced to form a long and slender snout, which is entirely enclosed in the skin, till just at its extremity, where there is an aperture for the protrusion of the cylindrical tongue. A bird-like character is the horny gizzard-like stomach. The anterior feet have four, and the posterior feet five toes, all armed with strong curved claws, which, in the case of the fore-feet, when not used in digging, are bent inwards, so that the animal walks on the sides of the feet; whereas the soles of the hind-feet touch the ground. The animal is perfectly harmless and gentle, when unmolested, and leads a solitary life. It lives mainly upon Termites, into the nests of which it forces its way by means of the powerful claws. When the Termites rush out to see what is the matter, the Ant-eater captures them by thrusting out its glutinous tongue, an action which can be repeated with marvellous rapidity.

In the closely-allied genus *Tamandua* the feet are four-toed, and the animal is arboreal in its habits, as is also the case with the species of *Cyclothurus*. In the latter the fore-feet are two-toed, and the hind-feet are four-toed, with a rudimentary hallux. In accordance with their mode of life these forms have prehensile tails, and in the last-mentioned genus well-developed clavicles are present.

3. *Manidæ*.—This family includes only the Scaly Ant-eaters or Pangolins (fig. 458), the species of which are exclusively confined to the Old World, and are found both in Africa and

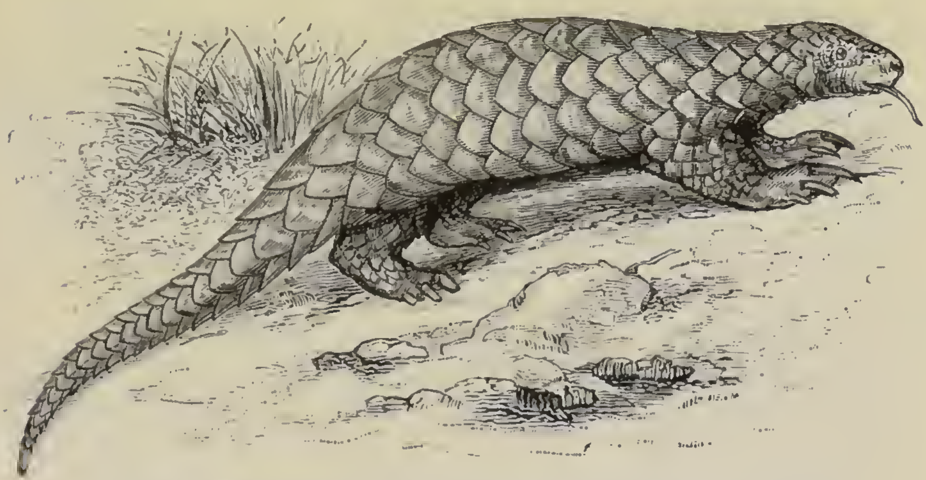


Fig. 458.—*Manis pentadactyla*, one of the Scaly Ant-eaters or Pangolins.

Asia. The skull is bird-like, the jaws toothless, and the zygomatic arch incomplete. The whole of the body, limbs, and tail in the *Manidæ* is covered with an armour of horny imbricated epidermic plates, overlapping like the tiles of a house, and apparently consisting of agglutinated hairs. The legs are short, and furnished with four or five toes each, ending in long and strong digging-claws; but there are no cla-

vicles. The tongue resembles that of the Hairy Ant-eaters in being long and contractile, and capable of being exserted for a considerable distance beyond the mouth. It is covered with a glutinous saliva, and is the agent by which the animal catches ants and other insects.

When threatened by danger, the Pangolins roll themselves up into a ball, like the hedgehogs. The tail is comparatively long, and is covered with scales. Though very strong for their size, only one of the species (*M. gigantea* of Africa) attains a length of more than three or four feet, inclusive of the tail. The best-known species are the *Manis pentadactyla* of India, and the *Manis tetradactyla* of Africa. Other species occur in Java, Sumatra, and China.

4. *Orycteropidæ.*—This family comprises the single genus *Orycteropus*, all the species of which are African. The body in this genus is covered with hair, and the animal puts the palms of the hands and the soles of the feet to the ground. The jaws are furnished with cylindrical molars (fig. 459), and

Fig. 459.—Skull of *Orycteropus capensis.*

the zygomatic arch is complete. The pectoral arch has well-developed clavicles.

Of the known species of *Orycteropus*, the most familiar is the *O. capensis*, which is peculiar to South Africa, and is known by the Dutch colonists as the "Aardvark" or Ground-hog. The animal is nocturnal in its habits, and lives upon insects. The body is elongated, and the tail is long, the species attaining a total length of four feet or more. The legs are short, and the feet plantigrade, the anterior pair having four unguiculate toes, the posterior five. The claws are strong and curved, and enable the animal to construct extensive burrows. The skin is very thick, and is thinly covered with bristly hairs; and the tail is hairy. The head is elongated, and the mouth small—devoid of incisor and canine teeth (fig. 459), but furnished with a number of cylindrical molars $\left(\frac{8-8}{6-6}\right)$. The crowns of the molars are flat, and they are composed of dentine traversed by numerous dichotomising pulp-cavities, their cross-section resembling a piece of bamboo cut across. The tongue is long, flat, and slender, and is covered by a sticky saliva, by the aid of which the animal catches insects. The head is long

and attenuated, the snout truncated and callous, and the ears large, erect, and pointed. Other species of *Orycteropus* occur in Senegal and Southern Nubia.

5. *Dasypodidæ.*—This family includes only the Armadillos, which are exclusively Neotropical in their distribution, and range from Patagonia to South Texas. The Armadillos are burrowing animals, furnished with strong digging-claws and well-developed clavicles. The jaws are furnished with numerous simple molars, which interlock with one another when the mouth is closed (fig. 456, B). In one species lateral incisors are present in the præmaxillæ. The zygomatic arch is complete. The body is more or less completely protected by an exoskeleton of epidermal scales underlaid by dermal bony scutes or shields, which are united to one another by sutures. In its most complete form, this exoskeleton is divided into

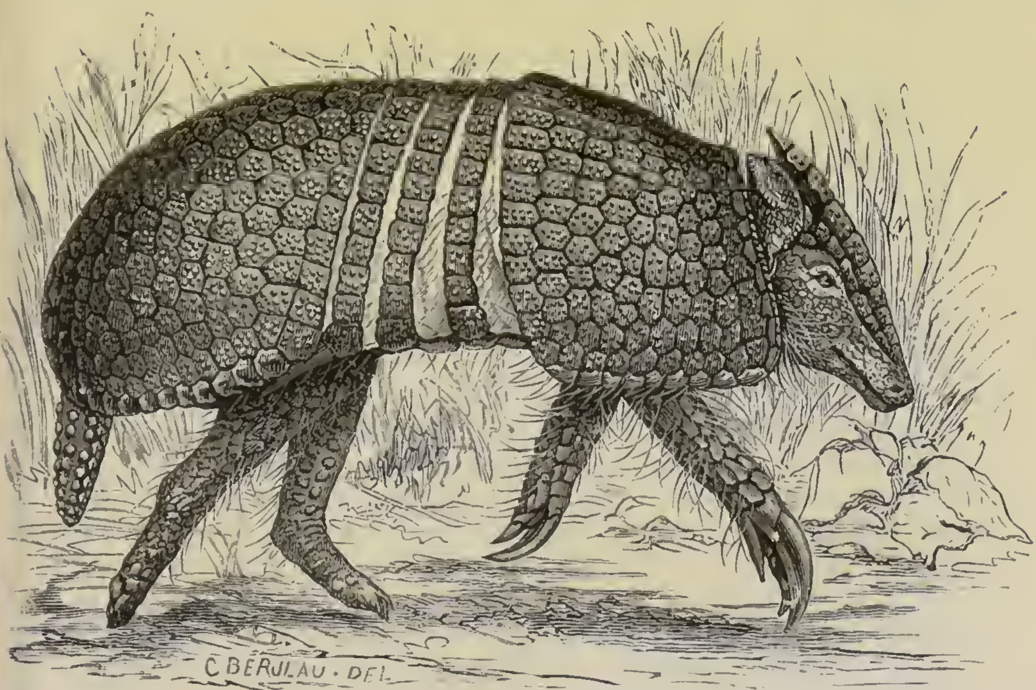


Fig. 460.—The three-banded Armadillo (*Tolypeutes conurus*), one-third of the natural size. (After Murie.)

separate sections, of which one covers the head and another the shoulders, the nape of the neck being protected by an intermediate series of nuchal plates, and a fourth series covering the hind-quarters. Between the pelvic and the scapular shields there is, typically, a series of movable bands of scutes, varying in number from three to thirteen, which run transversely to

the body, and give the necessary flexibility to this singular dermoskeleton. In some forms this flexibility is so great that the animal can roll itself up like a hedgehog. The tail is likewise mostly covered with bony scutes. The spinous processes of the second cervical and of all the dorsal vertebræ are specially developed to carry the dermal shield. The sternum and first rib are expanded, and sternal ribs are present.

The Armadillos vary in length from half a foot up to three feet, and live upon insects, worms, carrion, roots, and fruits. The largest living species is the Great Armadillo (*Priodontes gigas*), in which the molars reach the enormous number of nearly one hundred. The smallest is the aberrant little *Chlamydophorus truncatus*, which is only six inches long, and in which the dermal armour has the form of a long dorsal shield, composed of transverse bands of scutes, and attached in front to the frontal bone. Other well-known species are the *Peba* (*Dasypus peba*), the Poyou (*D. sexcinctus*), the Peludo (*D. villosus*), and the Pichiy (*D. minutus*). In the genus *Tolypeutes* (fig. 460), the animal walks upon the tips of the toes, and has the power of rolling itself into a ball.

As regards their *distribution in time*, the oldest Edentates at present known occur in Europe. These are the *Macrotherium* and *Ancylotherium* of the Miocene Tertiary (the latter also in the Oligocene), both apparently allied to the *Orycteropidæ*, with affinities to the *Manidæ*. The Pliocene deposits of North America have yielded to the researches of Professor Marsh two large *Edentates* of the new genus *Morotherium*, and the Miocene deposits of the same country contain the remains of another Edentate type (*Moropus*). It is, however, in the Post-tertiary deposits of the American continent, and especially of South America—the present metropolis of the order—that we find the most abundant and the most remarkable remains of Edentate animals. Here, both in Post-pliocene superficial deposits and in cave-earths of the same age, we meet with the remains of numerous Edentates often of gigantic size, but in the main representing the existing types.

Thus the existing Sloths are represented in the Brazilian bone-caves by a number of extinct genera of *Bradypodidæ*, whilst the Post-pliocene sands and gravels of the open country have yielded the bones of various huge Edentates, resembling the Sloths in most essential respects, but adapted for a terrestrial instead of an arboreal life. Of these great "Ground-sloths" (*Gravigrada*), the most remarkable are the *Megatherium*, which attained a length of eighteen feet, with bones as massive as, or more so than, those of the Elephant; and the *Mylodon* and *Megalonyx*, both of which extended their range into the United States.

In the same way the little banded Armadillos of South

America were formerly represented by gigantic species, constituting the genus *Glyptodon.* The *Glyptodons* (fig. 461) dif-

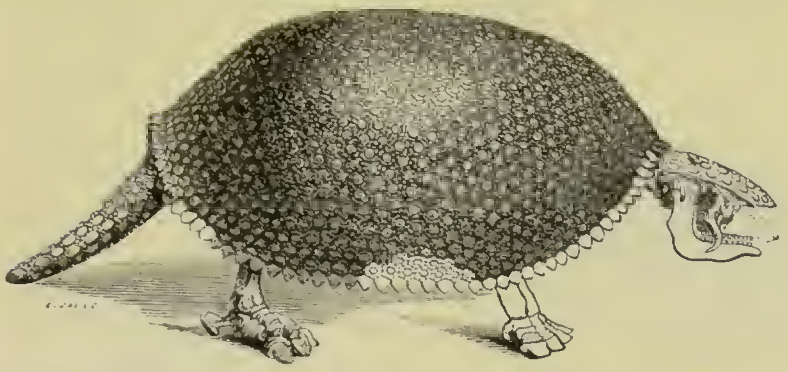


Fig. 461.—*Glyptodon clavipes.* Pleistocene deposits of South America.

fered from the living Armadillos in having no bands in their armour, so that they must have been unable to roll themselves up. It is rare at the present day to meet with any Armadillo over two or three feet in length; but the length of the *Glyptodon clavipes*, from the tip of the snout to the end of the tail, was more than nine feet. Besides the bandless Glyptodons, extinct forms of true Armadillos have been found in the Brazilian bone-caves, one of these (*Chlamydotherium*) being as big as a Rhinoceros. In the same deposits are also found extinct representatives of the *Myrmecophagidæ* (viz., *Glossotherium.*)

CHAPTER LXVI.

SIRENIA AND CETACEA.

Order IV. Sirenia.—This order comprises no other living animals except the Dugongs and Manatees, which have been often placed with the true *Cetacea* (Whales and Dolphins) in a common order. Though resembling the Cetaceans in their adaptation to an aquatic mode of life and in the absence of the pelvic limbs, the *Sirenia* are, however, really more closely allied to the Ungulates or Hoofed Quadrupeds than they are to the Cetaceans.

The *Sirenia* are *large aquatic Mammals, somewhat fish-like in form, the hinder end of the body being developed into a hori-*

zontal caudal fin formed by an expansion of the integuments. Hind-limbs are wanting, and the fore-limbs are converted into swimming-paddles or flippers. The muzzle is well developed, and the nostrils are placed upon its upper surface. The skin is fur-

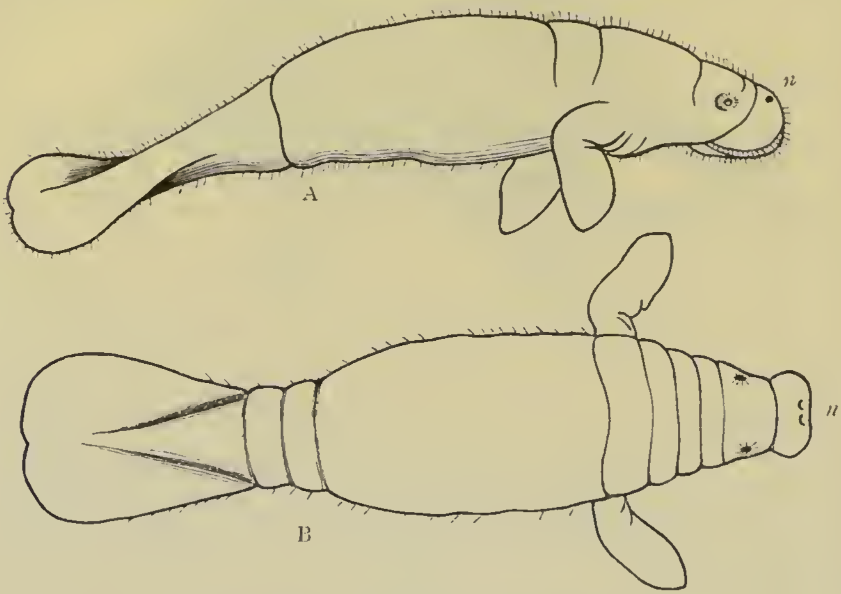


Fig. 462.—A, Side view of young *Manatus americanus*; B, The same viewed from above; *n* Nostrils. (After Murie.)

nished with scattered bristles. The jaws carry enamelled or non-enamelled molars with flattened crowns, adapted for bruising vegetable substances (horny plates instead of teeth in the extinct

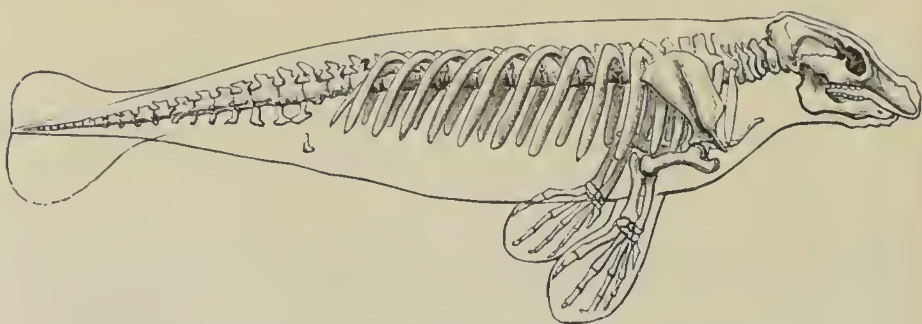


Fig. 463.—Skeleton of the Manatee (*Manatus americanus*).

Rhytina); *and the animal is diphyodont or monophyodont. The mammæ are two in number, and pectoral in position.*

The Sirenians are vegetable-feeders, and were for this reason termed "Herbivorous Cetaceans" by F. Cuvier. In the living species the jaws carry more or fewer molar teeth, which

have flattened crowns, while the front of the upper and lower jaws is furnished with rough horny pads or plates. In the genus *Rhytina*, now extinct, there were no true teeth, but the place of these was taken by plates of horn. Incisors are also present, but they do not cut the gum, except in the case of the upper incisors of the male Dugongs.

The cervical vertebræ are more or less largely free, and in *Manatus* are only six in number. No proper "sacrum" is present. The pelvis is rudimentary, and in the extinct genus *Halitherium* carried a rudimentary femur. In the living forms no traces of hind-limbs are present. The pectoral arch is without clavicles. The fore-limbs are shortened, and are converted into paddles or "flippers" (fig. 464), the digits being enclosed

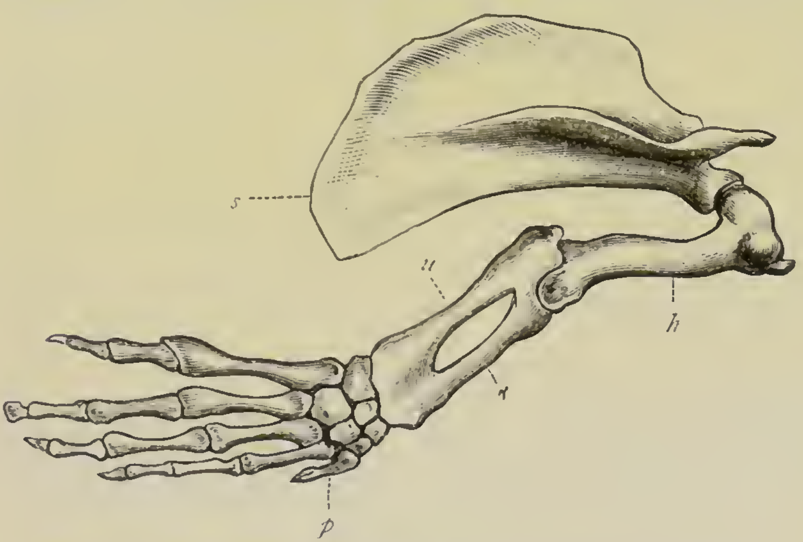


Fig. 464.—Fore-limb and hand of the Manatee (*Manatus americanus*).

in the skin. The shortening of the limb is, however, not nearly so marked as in the Cetaceans, and the digits not only never have more than three phalanges, but they may carry rudimentary nails. The principal organ of progression is, however, the tail-fin, which has the form of a flattened horizontal expansion of the skin. There is no dorsal fin, such as is found in many Cetaceans.

The skin is thick, but carries scattered bristles, which are particularly abundant in the neighbourhood of the mouth. The snout is fleshy, and the nostrils are borne on it, the nasal passages being inclined, whereas in the Cetaceans the nasal passages are vertical and the nostrils are placed on the top of the head. The ear is not provided with an external concha. The mammary glands are two in number, and are pectoral—a

fact which, taken in conjunction with the habit of the animal of partially raising itself out of the water, may sufficiently account for the "mermaids" of fable. The testes are retained throughout life in the abdomen, and vesiculæ seminales are present.

The only existing Sirenians are the Manatees (*Manatus*) and the Dugongs (*Halicore*), often spoken of as "Sea-cows." The living forms are entirely confined to the shores of the seas of hot regions, or to the rivers which flow into these seas, and they are found in both the Old and New Worlds. The extinct *Rhytina*, on the other hand, was an inhabitant of the Arctic Ocean.

The Manatees (*Manatus*, figs. 462, 463) are characterised by the possession of numerous $\frac{9-9}{9-9}$ to $\frac{11-11}{11-11}$ broad molars, which are never all in use at one time, while there are two small upper incisors, which do not cut the gum. The tail-fin is oblong or oval in shape (fig. 462), and the outer four digits are in some species provided with nails. They are essentially aquatic in their habits, and feed upon sea-weeds or river-plants. They are large, awkward animals, growing to a length of ten feet or more, and having a dense, rugose skin, with long, scattered bristles. Three living species of *Manatus* are known, of which one (*M. senegalensis*) inhabits the west coast of Africa, and makes its way up all the larger rivers far into the interior. A second species (*M. latirostris*) inhabits the Gulf of Mexico and the shores of the Antilles. The third (*M. americanus* or *M. inunguis*) is found on the east coast of South America, and inhabits the Amazon and its larger tributaries.

The Dugongs (*Halicore*, fig. 465, A) have $\frac{5-5}{5-5}$ or $\frac{6-6}{6-6}$ molar teeth in the young condition, but these are never all in use at one time. The molars are without enamel, and are single-rooted. Inferior incisors are

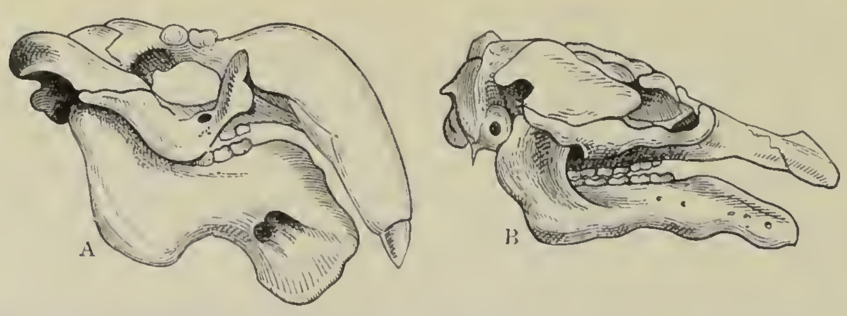


Fig. 465.—A, Side view of the skull of the Dugong (*Halicore*), showing the tusk-like upper incisors; B, Side view of the skull of Manatee (*Manatus*). (After Cuvier.)

present in the young animal, but are wanting in the adult. The upper jaw carries two permanent incisors, which are entirely concealed in the jaw in the females, but which increase in size in the males with the age of the animal, till they become pointed tusks. Both upper and lower jaws are strongly bent down in front, and the deflexed portions of the jaws bear

horny plates. The anterior extremities are nail-less, and the tail-fin is crescentic in shape. In their general appearance and in their habits the Dugongs differ little from the Manatees, but they are more strictly marine forms. They attain a length of from eight to ten, twelve, or more feet, and are found on the coasts of the Indian Ocean and its islands, extending their range to the north coast of Australia. The bones are remarkable for their extreme density, their texture being nearly as close as ivory.

The Manatees and Dugongs, as before said, are the only living *Sirenia;* but besides these there is a very singular form, the *Rhytina Stelleri*, which is now extinct, having been exterminated by man within a comparatively recent period. This remarkable animal was discovered about the middle of the eighteenth century in a little island (Behring's Island) off the coast of Kamtchatka. Upon this island the celebrated voyager Behring was wrecked, and he found the place inhabited by these enormous animals, which were subsequently described by M. Steller, who formed one of his party. The discovery, however, was fatal to the *Rhytina*, for the last appears to have been seen in the year 1768. The *Rhytina* was an animal of great size, measuring twenty-five to thirty-five feet in length, and twenty feet at its greatest circumference. There can hardly be said to have been any true teeth, but the jaws contained $\frac{1-1}{1-1}$ large lamelliform fibrous structures, which officiated as teeth, and may be looked upon as molars. These singular structures are not *teeth*, in the true sense of this term; but they are similar to the horny tuberculated plates found in the front of the mouth of the Dugong and Manatee, and the upper ones may be regarded as the equivalent of the anterior palatine pad of the Ruminants (Murie). The epidermis was extremely thick and fibrous, and hairs appear to have been wanting. There was a crescentic tail-fin, and the anterior limbs were exceedingly short.

As regards the *distribution in time* of the *Sirenia*, the oldest known remains referable to the order are found in the Eocene Tertiary (*Eotherium*). Of the same age is probably the interesting form described from the Tertiary deposits of Jamaica by Owen under the name of *Prorastomus sirenoides*. This type is remarkable as possessing upper and lower canines in addition to molar and incisor teeth. The Miocene and Pliocene deposits of Europe have yielded remains of numerous Sirenians belonging to various genera, the best known being *Halitherium*, in which there are tusk-like upper incisors (as in *Halicore*), combined with enamelled molars (as in *Manatus*), and in which a rudimentary femur is attached to the pelvis. Remains of *Rhytina* occur in the Post-pliocene of Siberia.

ORDER V. CETACEA.—This order includes the Whales, Dolphins, Porpoises, &c., which are characterised as being *aquatic fish-like Mammals, with a thick, smooth, and nearly or quite hairless skin. The hinder end of the body is furnished with a horizontal expansion of the integuments, constituting a caudal fin, and there may be an integumentary dorsal fin as well. There are no hind-limbs, or merely internal rudiments of such, and the*

fore-limbs are converted into paddles or flippers. The nasal passages have a vertical direction, and the nostrils (spiracle or blow-holes) are placed on the top of the head. The ear has no concha. Teeth may be wanting; and when present, are, in all living forms, simple, numerous, of one kind only, and one-rooted, the animal being monophyodont. The mammary glands are two in number, and are inguinal. The testes are retained throughout life within the abdomen, and there are no vesiculæ seminales.

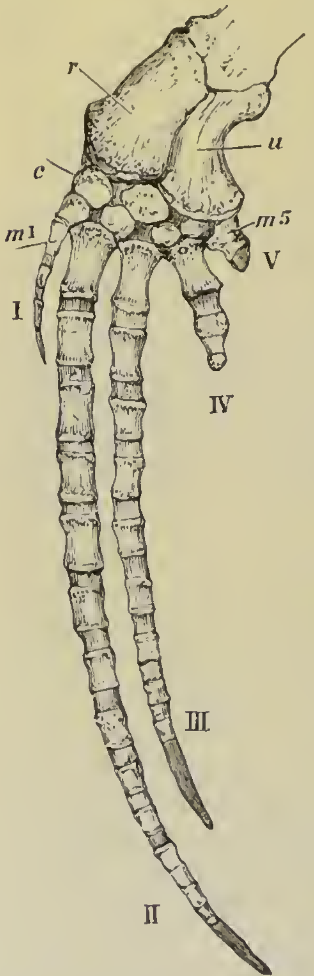


Fig. 466.—Hand of Round-headed Dolphin. I—V, Digits; *r* Radius; *u* Ulna; *c* Carpus; m^1, m^5 First and fifth metacarpal.

The body in the Cetaceans is fish-like, the head being of disproportionate size, and not separated from the body by any distinct constriction or neck. More or fewer of the cervical vertebræ are anchylosed with one another. There is no distinct "sacrum"; but a rudimentary pelvis is present. In the Toothless Whales there is often a rudimentary femur, and sometimes (*Balæna mysticetus*) a cartilaginous tibia as well. In the Toothed Cetaceans even these rudiments of hind-limbs appear to be wanting.

The pectoral arch is without a clavicle, and the sternum is broad and flat. The fore-limbs are converted into paddles or "flippers"; the humerus being much reduced in length (fig. 466), as also are the radius and ulna, which are firmly joined together. The digits are all completely enclosed in a tendinous skin, the hand being thus reduced to a nailless oar-like fin, while in some of the digits the number of phalanges is always increased (fig. 466).

The skull is more or less elongated, often unsymmetrically developed, and having the maxillæ and præmaxillæ more or less produced. The nasal passages are vertical, and are not covered by the much reduced nasal bones. Teeth may or may not be present, and when present are always simple (in living forms) and are usually numerous.

The skin is thick, and is underlaid by a thick stratum of subcutaneous fat (blubber). In the adult the skin is usually

totally hairless, but in some cases a very limited number of scattered hairs may be present on the lips.* The caudal fin is a great tendinous expansion of the integuments posteriorly, and in many cases the skin of the back is likewise raised into a dorsal fin.

The eyes are very small and without eyelashes. The ear has no concha, and the external meatus is exceedingly small. Owing to the vertical position of the nasal passages, the nostrils come to be placed on the top of the head, and constitute a single or double "blow-hole" or "spiracle." The animal can thus obtain air on rising to the surface, without exposing more than the upper portion of the head. The epiglottis and laryngeal cartilages are united to form a tube, which is prolonged upwards behind the soft palate, so as to come into apposition with the posterior nares, thus allowing the animal to swallow under water without choking. There are also great networks of blood-vessels (*retia mirabilia*) along the under surface of the spine and base of the skull, which have been supposed to store up blood during submersion. On rising to the surface to breathe, the animal expels from its lungs the air which had been contained in these organs, and which is thus charged with watery vapour. By the condensation of this vapour, the expired air acquires the appearance of a column of water; a certain amount of actual water being perhaps carried up along with the jet of expelled air, or driven out of the cavity of the nose along with the air. It is this phenomenon which is generally spoken of as the "blowing" or "spouting" of a Cetacean. The Cetaceans inhabit the sea, or rarely fresh waters, and are all carnivorous. They have a very wide distribution, and may be divided into the six families of the *Balænidæ* or Whalebone Whales, the *Delphinidæ* or Dolphins and Porpoises, the *Squalodontidæ*, the *Catodontidæ* or Sperm Whales, the *Rhynchoceti* or Ziphioid Whales, and the *Zeuglodontidæ*. Of these the *Balænidæ* are often spoken of as the "toothless" Whales, whilst the other five families are called the "toothed" Whales (*Odontoceti*).

Fam. 1. *Balænidæ*.—The *Balænidæ*, or Toothless Whales, are characterised by the total absence of teeth in the adult (fig. 467). Teeth are, however, present in the fœtal Whale, but they never cut the gum. The place of teeth is supplied by a number of plates of whalebone or "baleen" attached to the palate; hence the name of "whalebone whales" often

* Thus it has been shown by Professor Struthers that the lips of *Megaptera* possess a few scattered hairs, and these appendages have been recognised by the same observer in the case of others of the Finner Whales.

given to this family. They are the largest of living animals, and may be divided into the two sections of the *Smooth* Whales, in which the skin is smooth and there is no dorsal fin (as in the Greenland Whale), and the *Furrowed* Whales, in which the skin is furrowed and a dorsal fin is present (as in the so-called Finner Whales and Hump-backed Whales).

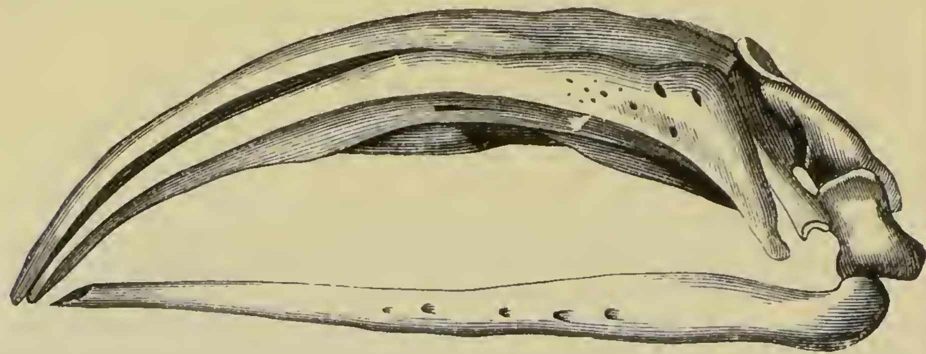


Fig. 467.—Skull of the Right Whale (*Balæna mysticetus*.) (After Owen.)

The Greenland or "Right" Whale (*Balæna mysticetus*) will illustrate almost all the leading points of interest in the family. The Greenland Whale is the animal which is sought after in the whale-fishery of Europe, and hence the name of "Right" Whale often applied to it. It is an inhabitant of the Arctic seas, and reaches a length of from forty to sixty feet. Of this enormous length, nearly one-third is made up of the head, so that the eye looks as if it were placed nearly in the middle of the body. The skin is completely smooth, and is destitute of hairs in the adult. The fore-limbs are converted into "flippers" or swimming-paddles, but the main organ of progression is the tail, which often measures from twenty to twenty-five feet in breadth. The mouth is of enormous size, the upper jaw much narrower than the lower, and both completely destitute of teeth. Along the middle of the palate runs a strong keel, bordered by two lateral depressions, one on each side. Arranged transversely in these lateral depressions are an enormous number of horny plates, constituting what is known as the "baleen" plates, from which the whalebone of commerce is derived. The arrangement of the plates of baleen is as follows (fig. 468): Each plate is triangular in shape, the shortest side or base being deeply sunk in the palate. The outer edge of the plate is nearly straight, and is quite unbroken. The inner edge is slightly concave, and is furnished with a close fringe formed of detached fibres of whalebone. For simplicity's sake each baleen-plate has been regarded here as a single plate, but in reality each plate is composed of several pieces, of which the outermost is by far the largest, whilst the others gradually decrease in size towards the middle line of the palate. The large marginal plates are from eight to ten or more feet in length, and there may be over one hundred on each side of the mouth.

The object of the whole series of baleen-plates with which the palate is furnished, is as follows: The Whale is a strictly carnivorous animal, but owing to the absence of teeth and the comparatively small calibre of the œsophagus, it necessarily lives upon very diminutive animals. The Whale, in fact, lives mostly upon the shoals of small Pteropodous Molluscs,

Crustacea, *Ctenophora*, and *Medusæ*, which swarm in the Arctic seas. To obtain these, the whale swims with the mouth opened, and thus fills the mouth with an enormous mass of water. The baleen-plates have the obvious function of a "screening apparatus." The water is strained through the numerous plates of baleen. and all the minute animals which

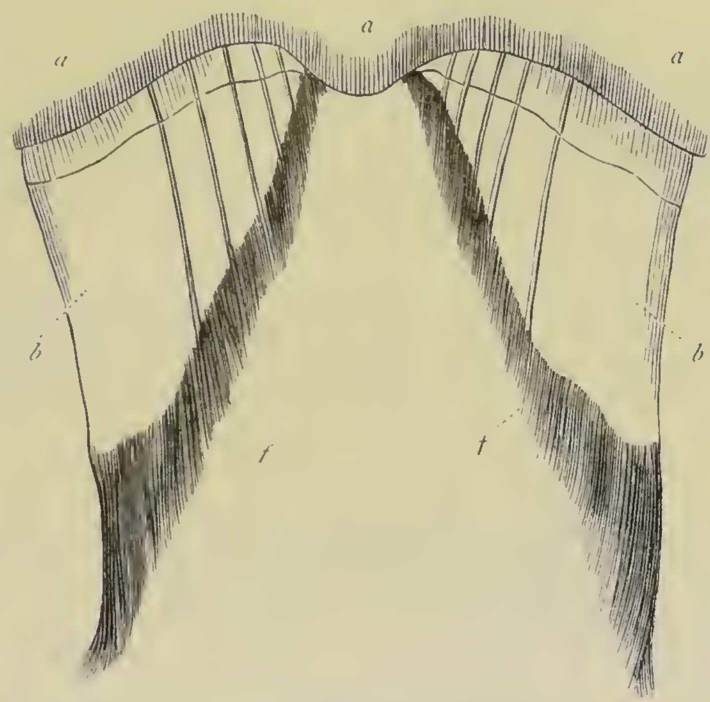


Fig. 468.—Diagram of the baleen-plates of a Whale. *a a* Section of the palatal surface of the upper jaw, showing the strong median ridge or keel; *b b* Baleen-plates sunk at their bases in the palate; *f f* Fibrous margin of baleen-plates.

it contains are arrested and collected together by the inner fibrous edges of the baleen-plates. When, by a repetition of this process, the Whale has accumulated a sufficient quantity of food within the central cavity of the mouth, it is enabled to swallow it without taking in the water at the same time.

The skin in the Right Whale is perfectly smooth and naked, but it is underlaid by a thick layer of subcutaneous fat, which varies from eight to fifteen inches in thickness, and is known as the "blubber." The blubber serves partly to give buoyancy to the body, but more especially to protect the animal against the extreme cold of the medium in which it lives. It is the blubber which is chiefly the object of the whale-fishery, as it yields the whale-oil of commerce.

The whale which is captured in the South Atlantic is not the same species as the Greenland Whale, and is termed the *Balæna australis*. It is much about the size of the Right Whale, averaging about fifty feet, but the head is proportionately smaller. Another Atlantic species is the *B. biscayensis*. In the South Pacific occurs *Balæna antipodarum*, and in the North Pacific we meet with the *B. japonica* along with the *B. mysticetus* or Right Whale of the North Atlantic (Van Beneden).

The only remaining members of the *Balænidæ* which require notice are

the Rorquals and Hump-backed Whales, constituting the group of the "Furrowed" Whales. These are collectively distinguished by having the skin furrowed or plaited to a greater or less extent, whilst the baleen-plates are short, and there is a dorsal fin. The specific determination of these animals is a matter of great difficulty, but there would appear to be probably three well-marked genera: 1. The genus *Megaptera*, including the so-called Hump-backed Whales, in which the flippers are of great length, from one-third to one-fifth of the entire length of the body. 2. The genus *Balænoptera*, comprising the so-called Rorquals or Piked Whales, in which the flippers are of moderate size. 3. The Finner Whales proper (*Physalus*).

In all these genera there is a dorsal adipose fin, so that they are all "Finner Whales." The *Balænopteræ* reach a gigantic size, being sometimes as much as eighty or one hundred feet in length. They are very active animals, however, and their whalebone is comparatively valueless, so that the whalers rarely meddle with them, though they are not uncommon, and are often driven ashore on our own coasts.

Fam. 2. *Catodontidæ.*—The family of the *Catodontidæ* or *Physeteridæ* comprises the Sperm Whales or Cachalots, with which we commence the series of toothed Whales (*Odontoceti*). They are characterised by the fact that the palate is destitute of baleen-plates, and the lower jaw possesses a series (from forty to fifty or more) of pointed conical teeth, separated by intervals, and sunk in a common alveolar groove, which is only imperfectly divided by septa. The upper jaw is also in reality furnished with teeth, but these do not cut the gum.

The best-known species of this family is the great Cachalot or Spermaceti Whale (*Physeter macrocephalus*, fig. 469). This animal is of enor-

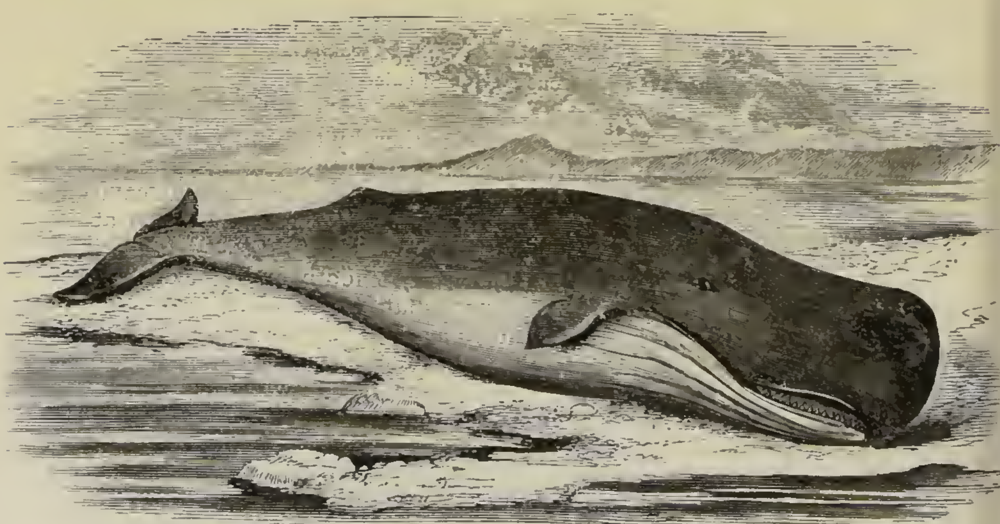


Fig. 469.—Spermaceti Whale (*Physeter macrocephalus*).

mous size, averaging from fifty to seventy feet in length, but the females are a good deal smaller than the males. The head is disproportionately large, as in the *Balænidæ*, forming more than one-third of the entire

length of the body. The snout forms a broad truncated muzzle, and the nostrils are placed near the front margin of this. The Sperm Whales live together in troops or "schools," and they are found in various seas, especially within the tropics. They are largely sought after, chiefly for the substance known as "spermaceti"; but besides this they yield oil and the singular body called "ambergris." The spermaceti is a fatty substance, which has the power of concreting when exposed to the air, being in life a clear white oily liquid. It is not only diffused through the entire blubber, but is also contained in special cavities of the head. The sperm-oil yielded by the blubber is exceedingly pure, and is free from the unpleasant odour of ordinary whale-oil. The ambergris is a peculiar substance which is found in masses in the intestine, and is probably of the nature of a biliary calculus, since it is said to be composed of a substance very nearly allied to cholesterine. It is used both as a perfume itself, and to mix with other perfumes.

Fam. 3. *Delphinidæ.*—This family includes the Dolphins, Porpoises, and Narwhal, and is characterised by usually possessing teeth in both jaws: the teeth being numerous, and conical in shape (fig. 470). The nostrils, as in the last family,

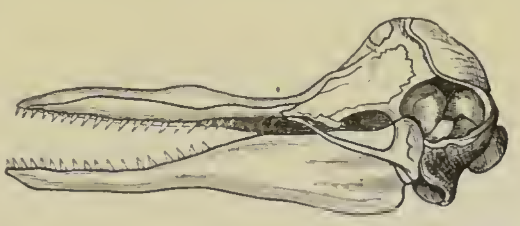


Fig. 470.—Side view of the skull of *Delphinus tursio*. (After Cuvier.)

are united, but they are placed further back, upon the top of the head. The single blow-hole or nostril is transverse and mostly crescentic or lunate in shape. The head is by no means so disproportionately large as in the former families, usually forming about one-seventh of the entire length of the body.

The most noticeable members of this family are the true Dolphins, the Porpoises, and the Narwhal.

The Dolphins have an elongated snout, separated from the head by a transverse depression. The common Dolphin (*Delphinus delphis*, fig. 471) is the best-known species. It averages from six to eight feet in length, and has a habit of swimming in flocks, often accompanying ships for many miles. The female, like most of the *Cetacea*, is uniparous. The Dolphin occurs commonly in all European seas, and is especially abundant in the Mediterranean.

The common Porpoise (*Phocæna communis*) is the commonest and smallest of all the *Cetacea*, rarely exceeding four feet in length. The head is blunt, and is not produced into a projecting muzzle. The Porpoise frequents the Atlantic, Pacific, Mediterranean, and Arctic Oceans, and the North Sea, and is commonly seen off our coasts. Another British species is

the Grampus (*Orca gladiator*), but this is much larger, attaining a length of from eighteen to twenty feet. Nearly allied to the Grampus is the so-called "Caing" Whale, or, as it is sometimes termed, the Bottle-nosed Whale (*Globicephalus melas* or *Phocæna globiceps*). This species occurs not

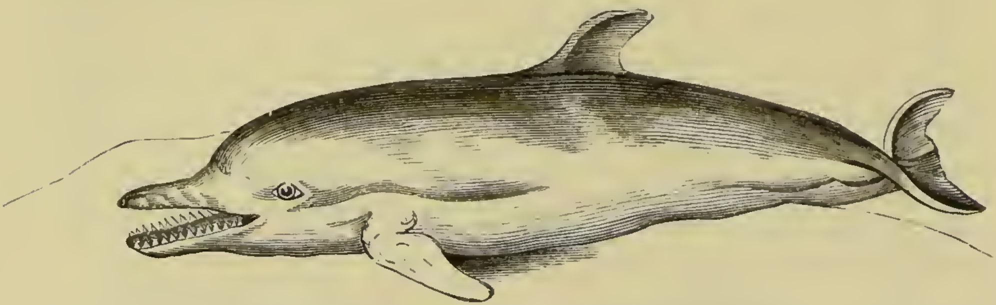


Fig. 471.—The Common Dolphin (*Delphinus delphis*).

uncommonly round the Orkney and Shetland Islands, and attains a length of as much as twenty-four feet. It is gregarious in its habits, and is often killed for the sake of its oil.

Closely allied to the true Dolphins are some curious Cetaceans, belonging to three genera, and all inhabiting fresh waters. One of these is the Gangetic Dolphin (*Platanista gangetica*), which inhabits the Ganges, especially near its mouth. This singular animal is characterised by the great length of its slender muzzle, and by the small size of the eyes. It attains the length of seven feet, and the blow-hole is a longitudinal fissure, and therefore quite unlike that of the typical *Delphinidæ*. Closely allied to this, or identical with it, is the *Platanista indi* of the Indus. Another fresh-water form is the *Inia boliviensis*, which inhabits the rivers of Bolivia, and is found at a distance of more than two thousand miles from the sea. Lastly, the *Pontoporia Blainvillii* is a small Dolphin which inhabits the mouths of the rivers of the Argentine Republic and of Patagonia, and also frequents the sea.

The last of the *Delphinidæ* is the extraordinary Narwhal or Sea-unicorn (*Monodon monoceros*). The Narwhal is an inhabitant of the Arctic seas, and attains a length of as much as fifteen feet, counting in the body alone. The dentition, however, is what constitutes the great peculiarity of the Narwhal. The lower jaw is altogether destitute of teeth, and the upper jaw in the females also exhibits no teeth externally, as a general rule at any rate, though there are two rudimentary canines which do not cut the gum. In the males the lower jaw is likewise edentulous, but the upper jaw is furnished with two molar teeth concealed in the gum, and with two canines. Of these two upper canines, that of the right side is generally rudimentary, and is concealed from view. The left upper canine, on the other hand, is developed from a permanent pulp, and grows to an enormous size, continuing to increase in length throughout the life of the animal. It forms a tusk of from eight to ten feet in length, and it has its entire surface spirally twisted. As an abnormality, both the upper canines may be developed in this way so as to form projecting tusks; and it is stated that the tusk is occasionally present in the female. The function of this extraordinary tooth is doubtless offensive.

Fam. 4. *Squalodontidæ*.—In the neighbourhood of the preceding family may be placed the extinct genus *Squalodon*, in

which the jaws are furnished with two kinds of teeth, the anterior teeth being conical, while the posterior teeth have serrated crowns, and are often two-rooted, though in other cases one-rooted. Though resembling the extinct family of the Zeuglodonts in their dentition, the Squalodonts approach the Dolphins in the structure of the skull. The species of *Squalodon* are confined to the Miocene and Pliocene Tertiary.

Fam. 5. *Rhynchoceti.*—This family is allied to the Cachalots or Sperm Whales, and includes the so-called "Ziphioid Whales." They are distinguished by the possession of a pointed snout (the "beak" or "rostrum"), single blow-hole, and small dorsal fin, and by their dentition. The upper jaw is greatly extended and is edentulous, any teeth which may be present not cutting the gum. The lower jaw, on the other hand, possesses usually a single pair of teeth, sometimes two pairs, which are sometimes tusk-like, but which in other cases are concealed by the gum, and are always most conspicuous in the males.

The rostrum of these Cetaceans is of great density, and has often been preserved in a fossil state, usually presenting itself as a bony cylinder or elongated cone, generally more or less water-worn. The most important living genera are *Hyperoödon* and *Ziphius,* of which the former is found in the North Atlantic, and the latter in the Mediterranean and South Atlantic. The genera *Berardius* and *Mesoplodon* belong to the New Zealand province, species of the latter having been also obtained at the Cape of Good Hope and on the coasts of Britain and France.

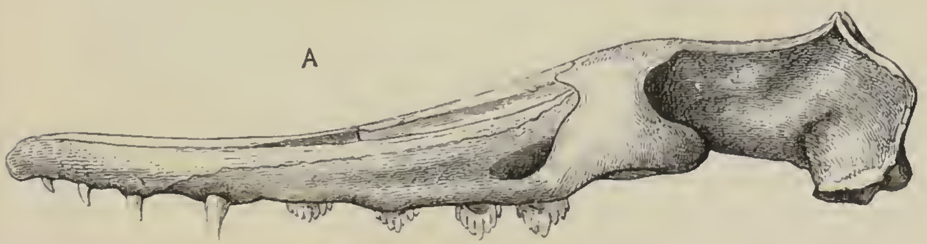


Fig. 472.—A, Restoration of the skull of *Zeuglodon*. B, Tooth of the same. (After Gaudry.)

Fam. 6. *Zeuglodontidæ.*—The members of this family differ from all existing *Odontoceti* in the possession of molar teeth implanted by two distinct fangs. Incisor teeth are likewise present, and the animal is diphyodont. The Zeuglodonts are entirely extinct, and they are exclusively confined to the Eocene, Miocene, and Pliocene periods.

The only genus included in this family (if the Squalodonts be regarded as forming a separate family) is *Zeuglodon* itself, characterised by the elongated snout, conical incisors, and molar teeth with triangular serrated crowns, implanted in the jaw by two roots. Each molar looks as if it were composed of two separate teeth united on one side by their crowns; and it is this peculiarity which is expressed by the generic name. The species of *Zeuglodon* are found in the Eocene and Miocene.

As regards the *distribution in time* of the *Cetacea*, no member of the order is as yet known with certainty to have existed during the Secondary period. The Zeuglodonts are confined to the Eocene and Miocene Tertiary, and the Squalodonts are found in Miocene and Pliocene deposits. The Whalebone Whales (*Balænidæ*) are represented in rocks as old as the Eocene. The Ziphioid Whales begin in the Pliocene, as do the *Catodontidæ;* but the *Delphinidæ* are known to occur in the Miocene Tertiary.

CHAPTER LXVII.

UNGULATA.

ORDER VI. UNGULATA.—The order of the *Ungulata*, or Hoofed Quadrupeds, is one of the largest and most important of all the divisions of the *Mammalia*. It corresponds with the two orders of the *Pachydermata* and the *Ruminantia* in the Cuvierian classification; the former of these comprising a number of thick-skinned and scantily-haired Ungulates, such as the Elephants, Rhinoceroses, Pigs, Hippopotamus, &c., while the latter included the Oxen, Sheep, Deer, Camels, and such other Ungulates as chew the cud or "ruminate." With the exception of the Elephants, which are now placed in the separate order of the *Proboscidea*, the two old orders above mentioned are now grouped together into the single order of the *Ungulata*, or Hoofed Quadrupeds, and the following are the characters of the order:—

All the four limbs are present, and that portion of the toe which touches the ground is always encased in a greatly-expanded nail, constituting a "hoof." Only in a few extinct forms (the Coryphodontidæ) are there more than four full-sized toes to each limb. In all living forms the pollex and hallux at least are wanting. Owing to the encasement of the toes in hoofs, the limbs are useless for prehension, and only subserve locomotion; hence clavicles are always wanting in the entire order. There are always two sets

of enamelled teeth, so that the animal is diphyodont. The molar teeth are massive, and have broad crowns adapted for grinding vegetable substances.

In accordance with the number of the digits (fig. 473), the

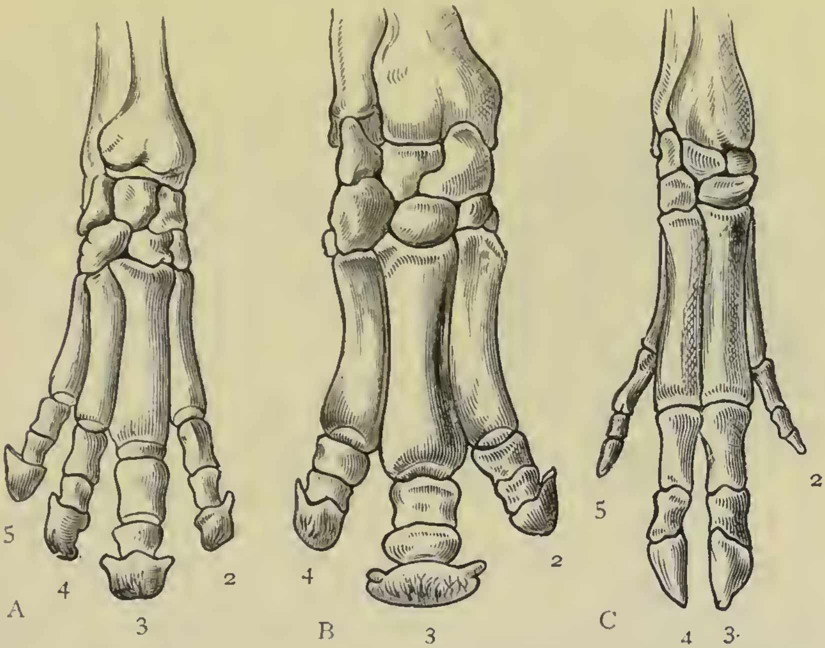


Fig. 473.—Feet of Ungulata. A, Fore-foot of Tapir (*Tapirus malayanus*); B, Perissodactyle fore-foot of *Rhinoceros sumatrensis;* C, Artiodactyle foot of Pig (*Sus scrofa*). The figures indicate which of the normal five digits are present in each foot. (After Flower.)

order *Ungulata* is divided into two primary sections: The *Perissodactyla*, in which the toes or hoofs are odd in number (one or three, or, in the extinct *Coryphodontidæ*, five), and the *Artiodactyla*, in which the toes are even in number (two or four).

Perissodactyle Ungulates.

Section A. Perissodactyla.—The section of the *Perissodactyle* Ungulates includes the Rhinoceros, the Tapirs, the Horse and its allies, and some extinct forms, all agreeing in the following characters :—

The hind-feet are odd-toed in all (fig. 473, B), *and the fore-feet in all except the Tapirs and Brontotheridæ, the third toe being the principal digit and being symmetrical in itself. The dorso-lumbar vertebræ are never less than twenty-two in number. The femur has a third trochanter. The horns, if present, are not paired (except in the extinct genus Diceratherium, and in the*

family of the Brontotheridæ). Usually there is only one horn, but if there are two, these are placed in the middle line of the head, one behind the other (fig. 477). *In neither case are the horns ever supported by bony horn-cores. The stomach is simple and not divided into several compartments; and there is a large and capacious cæcum.*

The three existing groups of Perissodactyle Ungulates—namely, the Horses, Tapirs, and Rhinoceroses—are widely removed from one another in many important characters; but the intervals between them are largely filled up by an extensive series of fossil forms, commencing in the Lower Tertiary strata.

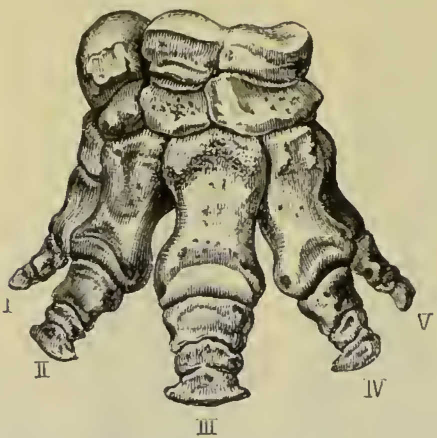


Fig. 474.—Fore-foot of *Coryphodon*. (After Marsh.) Eocene Tertiary.

The section of the Perissodactyle Ungulates includes the following seven families:—

Fam I. *Coryphodontidæ.*—This family comprises only a number of extinct Tapir-like animals, belonging to the Eocene period. The skull is of the Perissodactyle type, hornless, with small nasal bones. The brain is remarkably small, and the dentition is complete, the dental formula being—

$$i\,\frac{3-3}{3-3};\; c\,\frac{1-1}{1-1};\; pm\,\frac{4-4}{4-4};\; m\,\frac{3-3}{3-3} = 44.$$

The canines are not excessively developed, and the molars are of the Tapiroid type, having two transverse crests or ridges. The limbs are short, and both the fore-feet (fig. 474) and the hind-feet are furnished with five complete toes, all of which carried hoofs. The genus *Coryphodon* is the principal or only one comprised in the family; and as it contains the only Ungulates with the complete number of five digits on each foot, it might with propriety be raised to the rank of a distinct section, equal with the sections of the *Perissodactyla* and *Artiodactyla*, to which the name of *Teleodactyla* might be applied.

Fam. 2. *Rhinocerotidæ.*—This family comprises only a single living genus, the genus *Rhinoceros*, unless, indeed, the little *Hyrax* is to be retained in this order. The Rhinoceroses are extremely large and bulky brutes, having a very thick skin, which is usually thrown into deep folds. The feet (fig.

473, B) carry three toes each, the first and fifth digits being absent, and all the toes being hoofed, while a great palmar and plantar pad is developed behind the hoofs. The typical dental formula is—

$$i\,\frac{1-1}{1-1}\left(\text{or }\frac{0-0}{0-0}\right);\ c\,\frac{0-0}{0-0};\ pm\,\frac{4-4}{4-4};\ m\,\frac{3-3}{3-3}=32 \text{ or } 28.$$

There are no canines; and the incisors are often wanting in the adult (as in the living two-horned species), or may be increased in number (as in the extinct *Aceratherium*). The crowns of the præmolars and molars (fig. 475) exhibit two principal tracts of dentine, not filled up by cement.

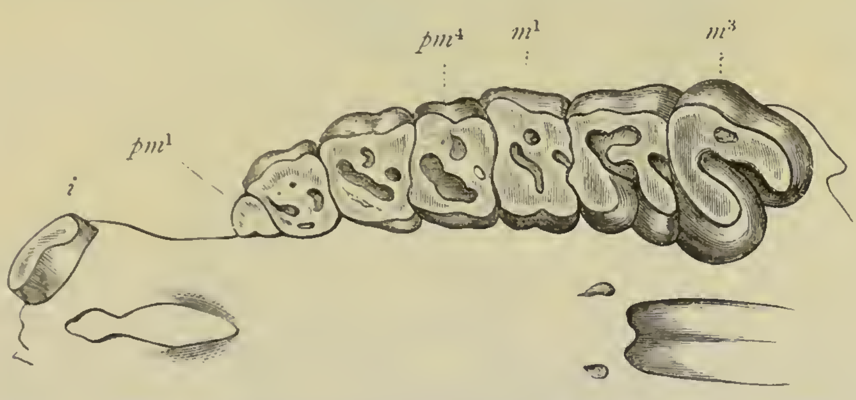


Fig. 475.—Teeth of the upper jaw of *Rhinoceros indicus* (after Cuvier). m^1, m^3 Molars; pm^1, pm^4 Præmolars; *i* Incisor.

The skull (fig. 476, B) is pyramidal, and the nasal bones are generally enormously developed. The nasal bones usually support one or two horns, which are not paired in any living form. The horn is composed of longitudinal fibres, which are agglutinated together, and are of the nature of epidermic growths, somewhat analogous to hairs. When two horns are present, the hinder one is carried by the frontal bones, and is placed in the middle line of the head behind the anterior horn. The posterior horn is usually much shorter than the anterior one; and if not, it differs in shape.

The development of the nasal bones in the Rhinoceroses varies greatly in accordance with the varying condition of the horns. In the extinct *Aceratherium*, in which there are no horns, the nasal bones are greatly reduced in size. In the horned forms, on the other hand, not only are the nasal bones prolonged forwards over the nasal cavity; but the septum narium may be partially or completely ossified, thus strengthening the basement of the anterior horn in the bicorn species.

The Rhinoceroses live in marshy places, and subsist chiefly on the foliage of trees. They are exclusively confined at the present day to the

warmer parts of the Old World; but several extinct species formerly ranged over the greater part of Europe.

The only existing one-horned Rhinoceroses are both found in the Oriental province. One of these is the common Indian Rhinoceros (*R.*

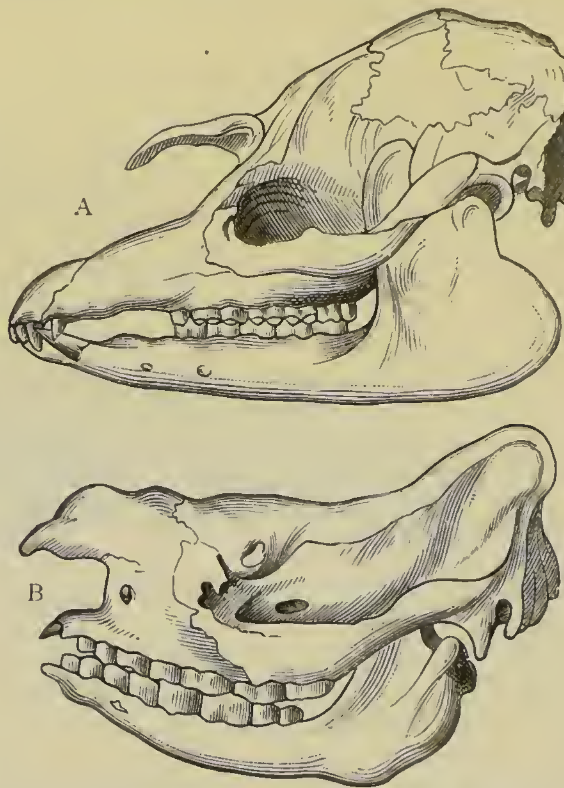


Fig. 476.—A, Side view of the skull of *Tapirus americanus;* B, Side view of the skull of *Rhinoceros bicornis.* (After Giebel.)

unicornis or *indicus*), which was probably the "Unicorn" of the ancients. The other is the Javan Rhinoceros (*R. sondaicus*), which inhabits the Malay peninsula, Java, Sumatra, and Borneo. Two species of bicorn Rhinoceroses are Asiatic, the best known being the Sumatran Rhinoceros (*R. sumatrensis*), which inhabits the Malay peninsula and Sumatra, and is remarkable for the comparative absence of cutaneous folds. All the African Rhinoceroses, of which there are four or five species, are two-horned. The best-known species are the White Rhinoceros (*R. simus*), the Black Rhinoceros (*R. bicornis*), and the Keitloa (*R. keitloa*).

As regards their *geological distribution*, the earliest types of the *Rhinocerotidæ* seem to have been hornless, and appear in the Eocene Tertiary of North America (*Amynodon*), and in the Miocene Tertiary of Europe (*Aceratherium*). The genus *Rhinoceros* itself appears in the Miocene, and is represented by numerous types in the later Tertiary deposits. One of the most remarkable of these is the Woolly Rhinoceros (*R. tichorhinus*), which was bicorn, and possessed the exceptional feature of a complete covering of long hair over the body. One of the most abnormal of the extinct Rhinoceroses is the *Diceratherium*, described by Professor Marsh from the Miocene deposits of Oregon, in which there are two horns placed trans-

versely and symmetrically upon the nasal bones. This singular form further differs from the typical Rhinoceroses in having four toes to the fore-feet, whilst the hind-feet have only three.

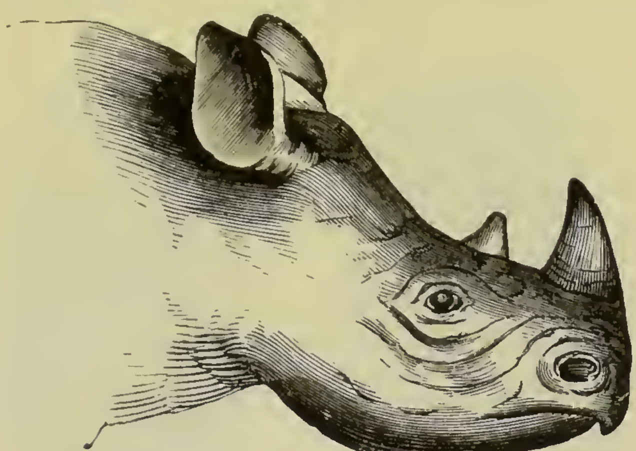


Fig. 477.—Head of the Black Rhinoceros (*R. bicornis*).

Fam. 3. *Tapiridæ.*—The Tapirs are characterised by the possession of a short movable proboscis or trunk. The skull (fig. 476, A) is pyramidal, like that of the pigs, and the nasal bones project over the nasal cavity. The skin is hairy and very thick. The tail is extremely short. The fore-feet (fig. 478, A) have *four* toes each, but these are unsymmetrical (the little toe being smaller than the rest and not touching the ground), and the hind-feet have only three toes, all encased in hoofs (fig. 478, B). The dental formula of the Tapirs is—

$$i\,\frac{3-3}{3-3};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{4-4}{3-3};\quad m\,\frac{3-3}{3-3}=42.$$

The canines are of comparatively small size, and do not form projecting tusks; and the molars and præmolars are of the "bilophodont" type, the crown of each showing two transverse or oblique ridges separated by shallow valleys.

Several species of Tapirs are known, of which the most familiar is the American Tapir (*T. americanus*), which inhabits the vast forests of South America. It is a large animal, something like a pig in shape, but brownish black in colour, and having a mane. It is nocturnal in its habits, and is strictly phytophagous. The proboscis is employed in conveying the food to the mouth, and the nostrils are placed at its extremity. It attains altogether a total length of from five to six feet. Another species, with longer hair (*T. villosus*), inhabits the Andes, and a still larger species (*T. malayanus*) is found in Sumatra, Borneo, and Malacca. In this last there is no mane, and the general colour is black; but the back, rump, and sides of the belly are white. The *Elasmognathus Bairdii* occurs in Central America, and one or more species of the genus *Tapirus* (*T. Roulini* and

T. leucogenys) have been discovered in the elevated regions of Ecuador and New Granada.

As regards their *distribution in time*, species of the genus *Tapirus* itself appear in the Miocene deposits of Europe. In the still older Eocene

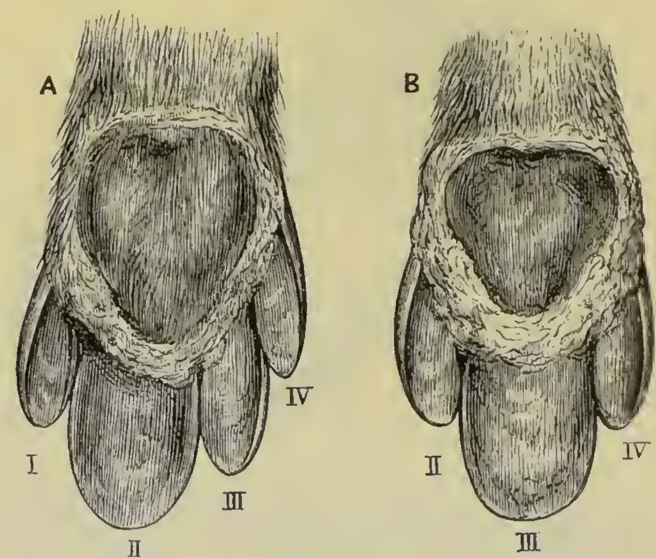


Fig. 478.—Feet of a Tapir, viewed from the hinder surface. (After Murie.) A, Fore-foot; B, Hind-foot.

Tertiary the remains of various Tapiroid animals are met with, of which the genus *Lophiodon* is one of the most important. The genus *Orohippus*, regarded by Marsh as an ancestral type of the *Equidæ*, seems to be identical with the Lophiodont genus *Hyracotherium*, and is found in the Eocene deposits.

Fam. 4. *Brontotheridæ.*—The large fossil Mammals from the Miocene of North America, which Professor Marsh has

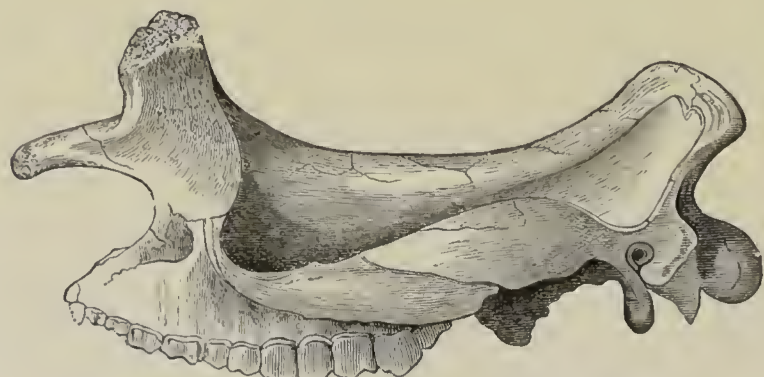


Fig. 479.—Skull of *Brontotherium ingens*. (After Marsh.)

described under the name of *Brontotheridæ*, may be provisionally placed here. In these, the fore-feet have four nearly

equal toes, and the hind-feet three, thus resembling the Tapirs. The skull is elongated, and a pair of very large horn-cores are carried upon the maxillaries and the anchylosed nasal bones in both sexes. The dental formula in *Brontotherium* is—

$$i\,\frac{2-2}{2-2};\ c\,\frac{1-1}{1-1};\ pm\,\frac{4-4}{3-3};\ m\,\frac{3-3}{3-3}=38.$$

The incisors are small; and the canines are short and not separated from the præmolars by any diastema, these latter being much smaller than the molars. The neck was long, and there seems to have been a long tail. The nose was probably elongated and flexible, but there would not appear to have been a long proboscis. The *Brontotheridæ* seem to be the successors of the *Dinocerata* of the Eocene. The chief genus is *Brontotherium*, with which the *Symborodon* and *Miobasileus* of Professor Cope are more or less entirely synonymous.

The genera *Titanotherium*, *Megacerops*, and *Diconodon* also belong to this group.

Fam. 5. *Palæotheridæ.*—This family includes certain extinct Ungulates from the Eocene and Miocene Tertiary. They are characterised by the possession of three toes to all the feet, by having canines, and by the fact that the lower molars have a doubly crescentic form. The canines are longer than the other teeth, and the dental formula is—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{4-4}{4-4}\left(\text{or }\frac{3-3}{3-3}\right);\ m\,\frac{3-3}{3-3}=44\text{ or }40.$$

The chief genus in this family is *Palæotherium* itself. Several species of this genus are known, varying in size from a sheep

Fig. 480.—Grinding-surface of the molar and præmolar teeth of the upper jaw of *Palæotherium crassum.* (After Owen.)

up to a horse. From the form and size of the nasal bones it is deduced, with great probability, that the *Palæotheridæ* possessed a short movable proboscis or trunk.

Fam. 6. *Macraucheniidæ.*—This family comprises the single genus *Macrauchenia* from the late Tertiary deposits of South America. The animals included in this genus were of large size, with three-toed feet, and a third trochanter to the femur,

but having cervical vertebræ of the type of those of the *Camelidæ*. The general form of the skull is horse-like, and the incisors have a coronal pit. The teeth form nearly a continuous series, and the dental formula is—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{4-4}{4-4};\ m\,\frac{3-3}{3-3}=44.$$

Fam. 7. *Solidungula* or *Equidæ.*—This family comprises the Horses, Asses, and Zebras, characterised by the fact that the feet, in living forms, have only a single perfect toe each, enclosed in a single broad hoof, without supplementary hoofs (figs. 438 and 484, D). The functional toe is the 3d, and the 2d and 4th digits are represented only by rudiments of their metapodials ("splint-bones"), hidden beneath the skin. There is a discontinuous series of teeth (fig. 481) in each jaw; and

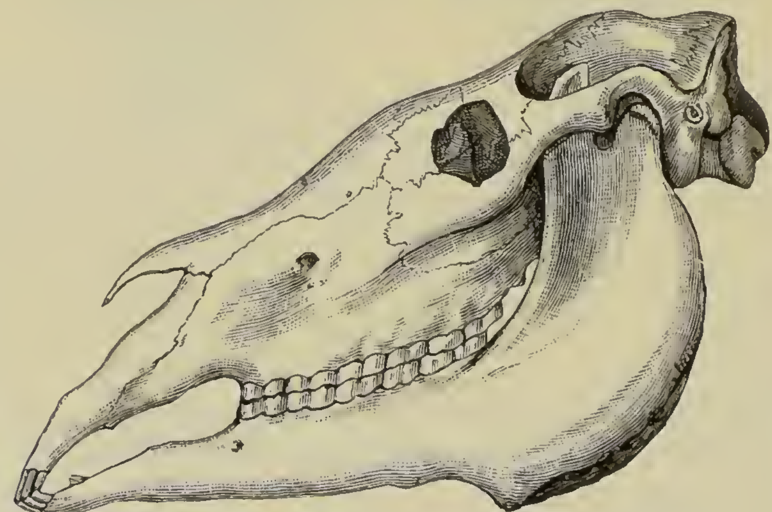


Fig. 481.—Skull of the Horse (*Equus caballus*).

in the males, canines are present, but these are wanting in the females. The dental formula is—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1}\left(\text{or }\frac{0-0}{0-0}\right);\ pm\,\frac{3-3}{3-3};\ m\,\frac{3-3}{3-3}=40\text{ or }36.$$

The skin is covered with hair, and the neck is furnished with a mane.

As regards the dentition, there are really four præmolars on each side of each jaw, but the first of these falls out at an early period, and resembles a milk-tooth in so far as it has no predecessor. The canines are of small size. The outer side of the molars (fig. 482) is deeply grooved, with two parallel

sulci, to which internal ridges correspond, their length being very great, and the whole external surface being thickly coated with cement; while the enamel-ridges and folds of the crown are filled in with the same substance. The enamel covering the incisors is folded in at the crown, like the inverted finger of a glove, the tube thus formed being filled in with soft

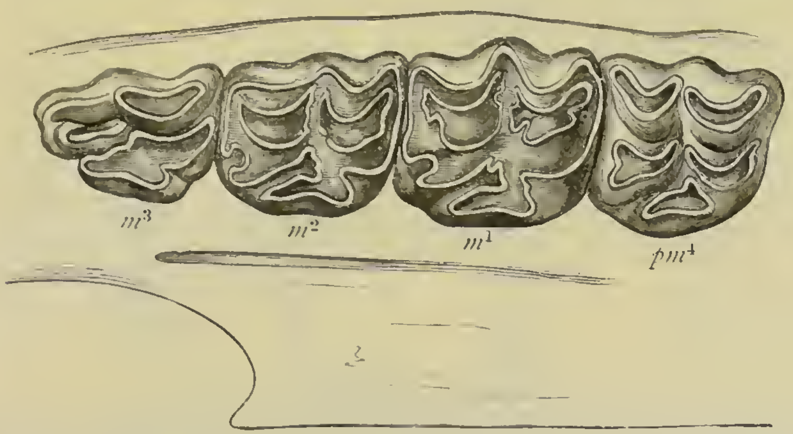


Fig. 482.—Grinding-surfaces of the last præmolar and of the three true molars of the upper jaw of the Horse. (After Cuvier.)

cement; and it is the wearing down of this with age which constitutes the "mark."

The family *Equidæ* is divided by Dr Gray into two sections or genera: *Equus*, comprising the Horses; and *Asinus*, comprising the Asses and Zebras. Many authorities, however, place all the existing forms under the single genus *Equus*.

The genus *Equus* is distinguished by the fact that the body is not banded, though a dorsal line is often present; both the fore and hind legs have warts upon them; the hoof is broad and rounded; and the tail is evenly haired, the long hairs beginning at or near the base. Until recently only a single living species of the genus was known—viz., the *Equus caballus*, from which have descended all the varieties of horses which are employed by man at the present day. The native country of the Horse seems to have been Central Asia, but the original stock of the domestic breeds is not known. All the so-called "wild" horses are in reality descendants of the domestic breeds, which have escaped and have reverted to a feral state. Recently a genuine wild species of the genus *Equus* has been found by Prjevalsky in the deserts between the Altai and Thian-Shan Mountains in Central Asia, and has been described under the name of *Equus Prjevalskii*. This remarkable species (fig. 483) differs from *Equus caballus* in the fact that the long hairs of the tail do not begin till about half-way down, while the mane is short and erect, and there is no fore-lock. It is of small size, with thick legs, and a large heavy head. In the genus, or sub-genus, *Asinus*, the body is marked with a dorsal stripe, and generally with a shoulder stripe, or it is completely striped; the fore-legs alone have warts; the hoof is contracted; and the long hairs of the tail form a tuft at the end. The

domestic Ass (*Asinus vulgaris*) is believed to be descended from the wild *Asinus tæniopus* of Upper Nubia, which has transverse stripes on its hind legs. The "Onager" (*Asinus onager*) of the Asiatic deserts is another wild species, and a third well-known form is the "Kiang" (*Asinus hemionus*) of the high table-lands of Thibet. Wholly confined to Africa, lastly, are the striped and banded species known as the Zebras (*A. zebra* and *A. burchellii*) and Quaggas (*A. quagga*).

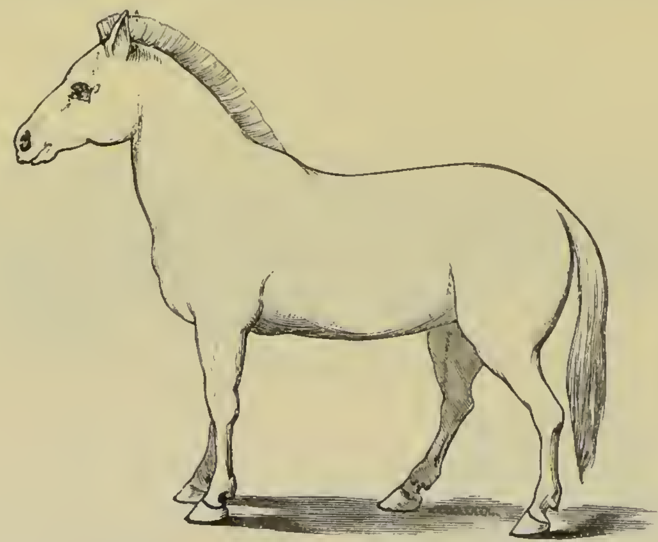


Fig. 483.—*Equus Prjevalskii.* (Copied from "Nature").

As regards their *distribution in time*, a number of forms of fossil *Equidæ* have been discovered, many of which are of special interest, as showing an almost perfect series of gradations between a foot with three complete toes and a foot with only one complete digit. Some of them also exhibit other curious transitional characters.

According to the views entertained by Professor Marsh, the most ancient type of the *Equidæ* is the *Eohippus* of the Lower Eocene of North America, in which the fore-feet have four complete toes and a rudimentary pollex, while the hind-feet have three toes.

Orohippus, probably really referable to the Tapiroid group of the *Lophiodontidæ*, is regarded by Marsh as the next oldest known Equine genus, and comprises small mammals about as big as foxes, with the fore-feet four-toed (fig. 484, A), and the hind-feet three-toed. In the fore-foot, the pollex alone is wanting, but the middle toe is much the largest. The genus is from the Eocene of North America.

In the Miocene Tertiary occur the genera *Anchitherium*, *Miohippus*, and *Mesohippus*, all of which have three toes to both feet. *Mesohippus* has an additional "splint-bone" (rudimentary metacarpal, or metatarsal) representing a fourth toe. *Miohippus*, about as big as a sheep, has the three toes sub-equal, and all touching the ground. *Anchitherium* (fig. 484, B) has the middle toe much the largest, though the lateral toes still reach the ground.

In the later Miocene and earlier Pliocene we find the genus *Hipparion*, in which the foot is still three-toed (fig. 484, C); but the middle toe is alone functionally useful, the two lateral toes, though appearing externally, not being long enough to touch the ground.

In the later Pliocene we meet with the genus *Pliohippus*, in which the

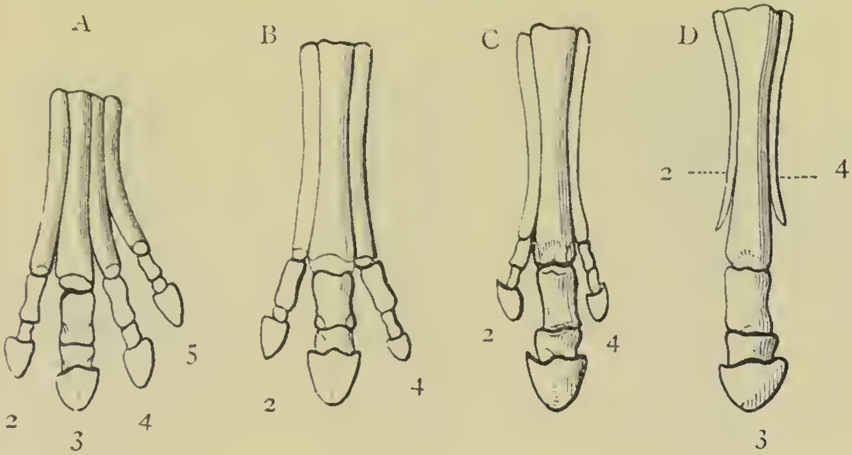


Fig. 484.—Skeleton of the foot in various forms belonging to the family of the *Equidæ*: A, Foot of *Orohippus*, Eocene; B, Foot of *Anchitherium*, Upper Eocene and Lower Miocene; C, Foot of *Hipparion*, Upper Miocene and Pliocene; D, Foot of Horse (*Equus*), Pleistocene and Recent. The numerals indicate the numbers of the digits in the typical five-fingered hand of Mammals. (After Marsh.)

foot is precisely that of *Equus*, with the lateral toes reduced to splint-bones (fig. 484, D), but there is an additional præmolar, and an "antorbital fossa" is present. Lastly, in the Post-pliocene appears the genus *Equus* itself.

CHAPTER LXVIII.

UNGULATA (*Continued*).

Artiodactyle Ungulates.

Section B. Artiodactyla.—In this section of the Ungulates *the number of the toes is even—either two or four—and the third toe on each foot forms a symmetrical pair with the fourth* (fig. 485). *The dorso-lumbar vertebræ are nineteen in number, and there is no third trochanter on the femur. If true horns are present, these are always in pairs, and are supported by bony horn-cores. The antlers of the Deer are also paired, but they are composed wholly of bone. The stomach is always more or less complex, or is divided into separate compartments, and the cæcum is comparatively small and simple.*

In all the Artiodactyles, the third and fourth toes are symmetrically paired, and in all but the *Hippopotamidæ*, they are

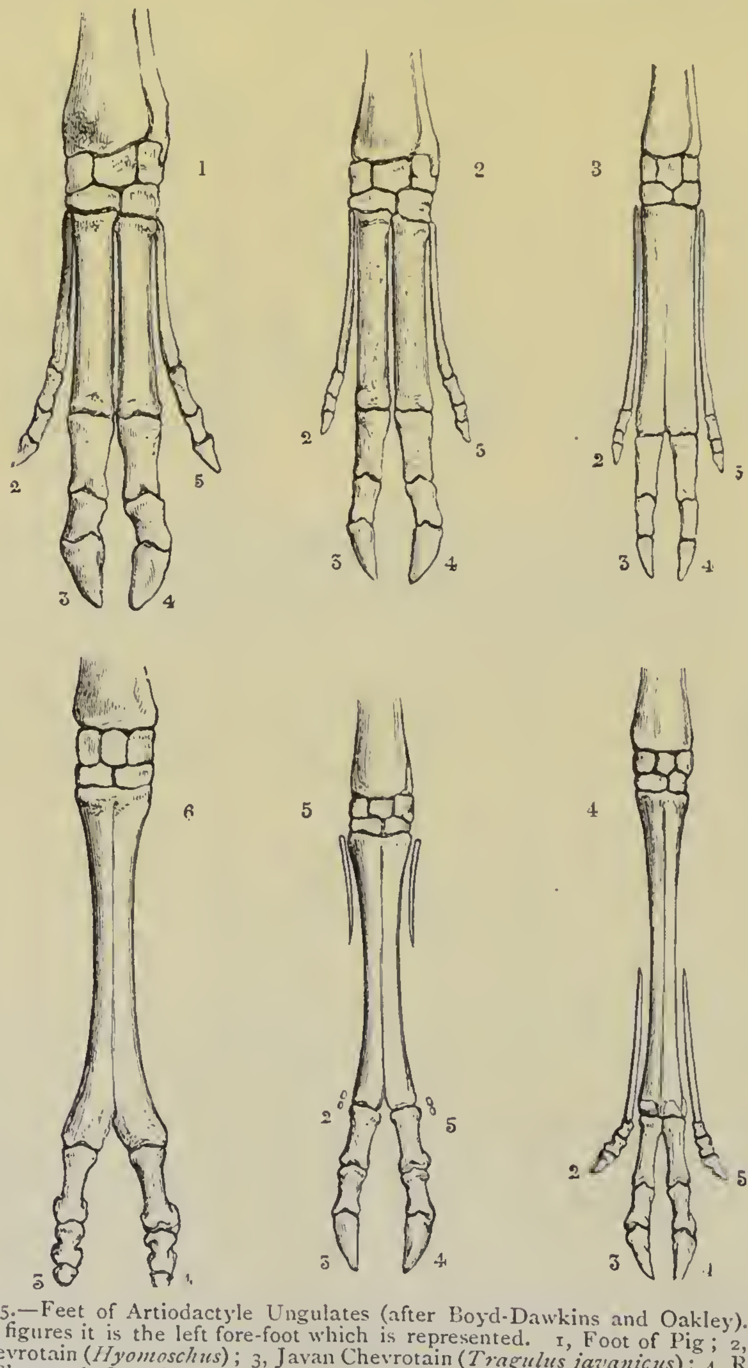


Fig. 485.—Feet of Artiodactyle Ungulates (after Boyd-Dawkins and Oakley). In all the figures it is the left fore-foot which is represented. 1, Foot of Pig; 2, African Chevrotain (*Hyomoschus*); 3, Javan Chevrotain (*Tragulus javanicus*); 4, Roebuck; 5, Sheep; 6, Camel. The small numerals indicate which digits are present.

the two functional toes of the foot. In the Hippopotamus

(fig. 489), the second and fifth digits are sufficiently developed to take part in supporting the weight of the body. In the Swine, the second and fifth toes are moderately developed (fig. 485, 1), but they are placed high up, and do not touch the ground when the animal is walking on a plane and hard surface. In these two groups also, the metapodials (metacarpals and metatarsals) remain permanently distinct. In the Chevrotains (*Tragulidæ*), the second and fifth toes are complete, but very small; and the metapodial bones either remain separate, as in *Hyomoschus* (fig. 485, 2), or only unite late in life (fig. 485, 3). In the Hollow-horned Ruminants generally, as in Deer and Sheep (fig. 485, 4 and 5), the second and fifth toes are reduced to rudiments, and the metapodials of the third and fourth toes, which are alone functional, become completely anchylosed to form a "cannon-bone." Lastly, in forms like the Giraffe and Camel (fig. 485, 6), the second and fifth toes disappear altogether, and the metapodials of the functional third and fourth toes are anchylosed to form a "cannon-bone."

By Kowalewsky, the *Artiodactyla* are divided into two great

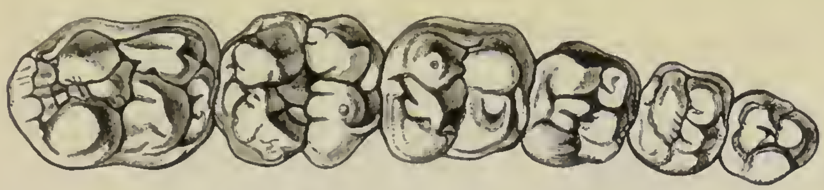


Fig. 486.—Grinding-surface of the molar and præmolar teeth of a Peccary (*Dicotyles labiatus*), showing the bunodont type of dentition. (After Giebel.)

groups or sections in accordance with the nature of the teeth. These two sections were differentiated at a very early period, and they are known respectively as the *Bunodontia* and *Seleno-*

Fig. 487.—Grinding-surface of the molar and præmolar teeth of the Giraffe (*Camelopardalis giraffa*), showing the selenodont type of dentition.

dontia. In the "Bunodont" section are comprised only the Pigs and their allies, and the *Hippopotamidæ*, in all of which the molars and præmolars have tuberculated crowns (fig. 486). In the "Selenodont" section of the *Artiodactyla* the præmolars

and molars (fig. 487) have the grinding-surfaces of their crowns divided each into two crescentic lobes, the convexities of which are turned inwards in the upper and outwards in the lower teeth. Some fossil forms, which are otherwise allied to the Bunodont Artiodactyles, show teeth of a "selenodont" character, and thus form a transition between these otherwise sharply separated divisions of even-toed Ungulates.

The section *Artiodactyla* comprises the Hippopotamus, the Pigs, and the whole group of the Ruminants, including Oxen, Sheep, Goats, Antelopes, Camels, Llamas, Giraffes, Deer, &c. Besides these there is an extensive series of fossil forms commencing in the Eocene or Lower Tertiary period, and in many respects filling up the gaps between the living forms.

BUNODONTIA (*Non-ruminantia*).

Fam. I. *Hippopotamidæ.*—This group contains only the single genus *Hippopotamus*, characterised by the massive heavy

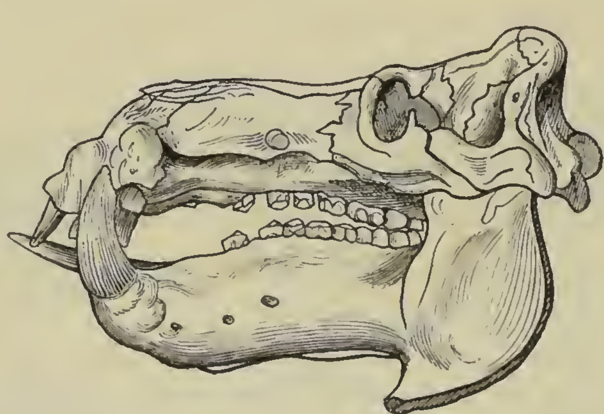


Fig. 488.—Skull of a *Hippopotamus amphibius*, side view. (After Giebel.)

body, the short blunt muzzle, the large head, and the presence of teeth of three kinds in both jaws (fig. 488). The dental formula of the living *Hippopotamus amphibius* is—

$$i\,\frac{2-2}{2-2};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{4-4}{4-4};\quad m\,\frac{3-3}{3-3} = 40.$$

The incisors are nearly horizontal, those of the centre of the lower jaw being long and tusk-like. The canines are greatly developed, those of the upper jaw being comparatively short, while the lower canines are in the form of enormous tusks, with a chisel-shaped edge. The crowns of the molars exhibit

a characteristic double-trefoil pattern. The legs are very short, with massive feet, terminated by four hoofed toes each (fig. 489). The eyes and ears are small, and the skin is extremely thick, and is furnished with a few bristles on the very short tail.

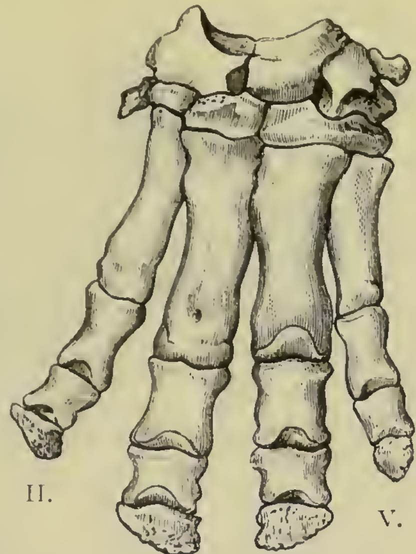


Fig. 489.—Left fore-foot of *Hippopotamus amphibius*. (After Cuvier.)

A number of extinct species of *Hippopotamus* are known; but there is only one familiar living form, the *Hippopotamus amphibius* or River-horse, and this is confined to the African continent. It is an enormously bulky and unwieldy animal, reaching a length of eleven or twelve feet. It is nocturnal in its habits, living upon grass, the foliage of trees, and herbs, and it swims and dives with great facility. It is found in tolerable abundance in all the great rivers of Africa south of the Sahara. A much smaller form (the so-called *Hippopotamus* or *Chœropsis liberiensis*) occurs on the west coast of Africa, but it is exceedingly rare, and comparatively little is known about it. It possesses, however, only two lower incisors instead of four.

Fam. 2. *Suidæ.*—The group of the *Suidæ*, comprising the Pigs, Hogs, and Peccaries, is closely allied to the preceding; but the feet (fig. 485, 1) have only two functional toes, the second and fifth toes being much shorter, and hardly touching the ground. All the three kinds of teeth are present, but they vary a good deal. The canines (fig. 490) are always very large, and trihedral in shape; and in the males they usually constitute formidable tusks projecting from the sides of the mouth. The incisors are variable, but the lower ones are always inclined forwards. The molars and præmolars have broad crowns, with two transverse ridges (increased to three or more in the last molar), which are divided into rounded tubercles (fig. 486). The permanent dental formula of the Pig (*Sus scrofa*) is—

$$i\,\frac{3-3}{3-3};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{3-3}{3-3};\quad m\,\frac{3-3}{3-3}=40.$$

In the young animal there are four deciduous molars, but the first of these is not replaced by a præmolar, though it remains in the jaw up to the third year of life. If, therefore, the jaw

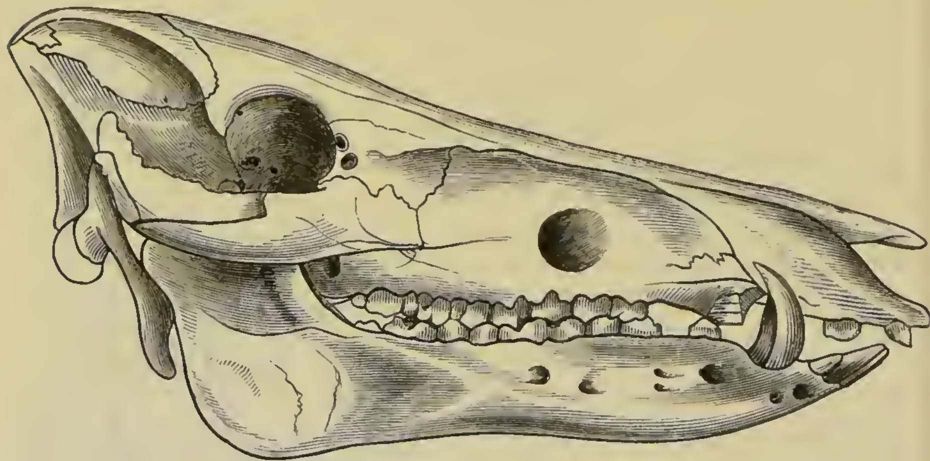


Fig. 490.—Skull of the Wild Boar (*Sus scrofa ferus*). (After Gray.)

of a Pig up to the third year of its age (fig. 491) be examined, there will appear to be four præmolars and three molars on each side, the first of these apparent præmolars being really the long-retained first deciduous molar. The skull is remark-

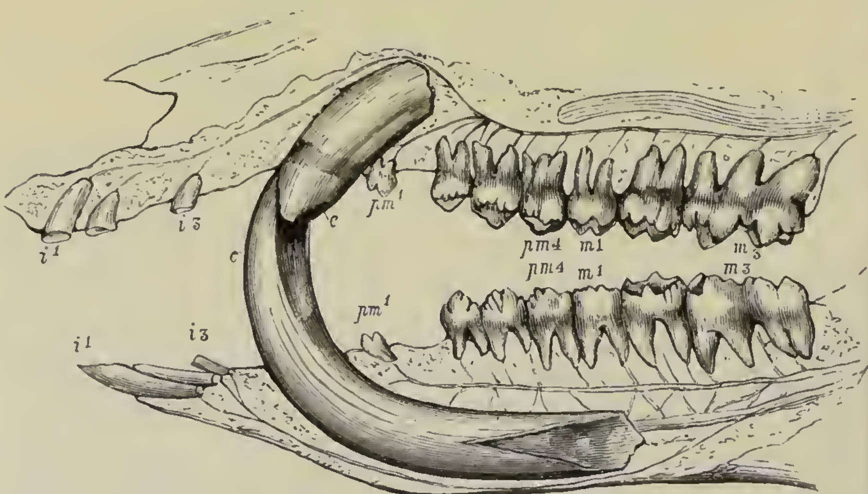


Fig. 491.—Dentition of the Boar (*Sus scrofa*). The tooth marked *pm*1, though taking the place of a first præmolar, is really the first deciduous molar, which has not yet been shed.

ably pyramidal, with a pointed occiput and long paroccipital processes (fig. 490). The stomach is mostly slightly divided, and is not nearly so complex as in the Ruminants. The snout

is truncated and cylindrical, fitted for turning up the ground, and capable of considerable movement, being strengthened by a prænasal bone, or ossification of the septum narium. The skin is more or less abundantly covered with hair, and the tail is very short, or represented only by a tubercle.

The most familiar example of the *Suida* is the Wild Boar (*Sus scrofa*), from which many of our domestic breeds of Pigs have descended. The Wild Boar, as also the domestic Pig, both when tame and in a wild state, exhibits remarkable powers of adaptation to different conditions of climate and general surroundings. The natural range of the Wild Boar is coextensive with the Palæarctic province, but it has been exterminated in various regions which it once inhabited, as for example, in Britain. About a dozen other species of the genus *Sus* are known, ranging over the Palæarctic and Oriental provinces, and extending eastwards as far as New Guinea, but being absent from North and South America and Australia. Of the remaining *Suida*, one of the most singular is the Babyroussa (*Porcus babirusa*), which inhabits the islands of Celebes and Borneo in the Melanesian province. It is remarkable for the great size and backward curvature of the upper canines. The upper canines pierce the upper lip in the males, and their alveoli are directed upwards. The Bush-hogs (*Potamochœrus*) of Southern Africa and Madagascar are nearly allied to *Sus*, but possess subocular excrescences of a cartilaginous nature. The African Wart-hogs, forming the genus *Phacochœrus*, are distinguished by having a fleshy wart under each eye. They inhabit Abyssinia, the Guinea coast, and other parts of Africa.

The American Peccaries (*Dicotyles*) represent the Swine of the Old World. They are singular in having only three toes on the hind-foot, the fifth digit being represented only by its metatarsal. The canines are not exserted, there are only four upper incisors, and there is no tail. There is also the exceptional character that the metapodials unite to form a "cannon-bone." They are exclusively confined to the American continent, extending from Paraguay as far north as Texas and Arkansas, and the commonest species is the Collared Peccary (*Dicotyles torquatus*). They are not at all unlike small pigs either in their appearance or in their habits, and they are gregarious, generally occurring in small flocks.

Fam. 3. *Anoplotheridæ.*—This group comprises extinct Artiodactyles which belong to the Eocene and Miocene periods, and form a kind of transition between the Swine and the Ruminants. In *Anoplotherium* itself (fig. 492) the body is slender, provided with a long tail, and having the feet terminated by two toes each, sometimes with small accessory hoofs in addition. The dentition is remarkable in the fact that no gap or diastema exists between the molars and the canines, the teeth thus forming an even and uninterrupted series. The dental formula is—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{4-4}{4-4};\ m\,\frac{3-3}{3-3} = 44.$$

Fam. 4. *Oreodontidæ.*—This family comprises extinct Artio-

dactyles from the Miocene and Pliocene Tertiary of North America, which stand in some respects midway between the *Suida* and the *Ruminantia*, and have been termed "Ruminat-

Fig. 492.—*Anoplotherium commune.* Eocene Tertiary, France. (After Cuvier.)

ing Hogs," though there is no evidence that they really ruminated. *Oreodon* is about as big as a sheep, the feet being four-toed, and the dental formula "complete." The canines are large and triangular, and the molars are of the "selenodont" character, while there is the anomalous distinction that "larmiers" or "tear-pits" existed below the eyes.

SELENODONTIA (*Ruminantia*).

The last section of the *Artiodactyle* Ungulates is the great and natural group of the Selenodont or Ruminant Ungulates. This section comprises the Oxen, Sheep, Antelopes, Giraffes, Deer, Camels, &c., and is distinguished by the following characters:—

The foot is what is popularly called "cloven," consisting of a symmetrical pair of toes encased in hoofs and looking as if produced by the splitting into two equal parts of a single hoof. Besides the two functional toes (the 3d and 4th), the 2d and 5th toes are usually present as a pair of small supplementary digits placed on the back of the foot. The metacarpal bones of the two functional toes of the fore-limb, and the metatarsal bones of the same toes of the hind-limb, except in *Hyomoschus*, coalesce to form a single bone, known as the "cannon-bone." The stomach is complex, and is divided into several compartments, this being in accordance with their mode of eating. They all, namely, ruminate or "chew the cud"—that is to say, they first swallow their food in an unmasticated or partially-masticated condition, and then bring it up again, after a longer or shorter time, in order to chew it thoroughly.

The process of rumination is so characteristic of this group, that it will be necessary to describe the structure of the stomach, as showing the mechanism by which this singular process

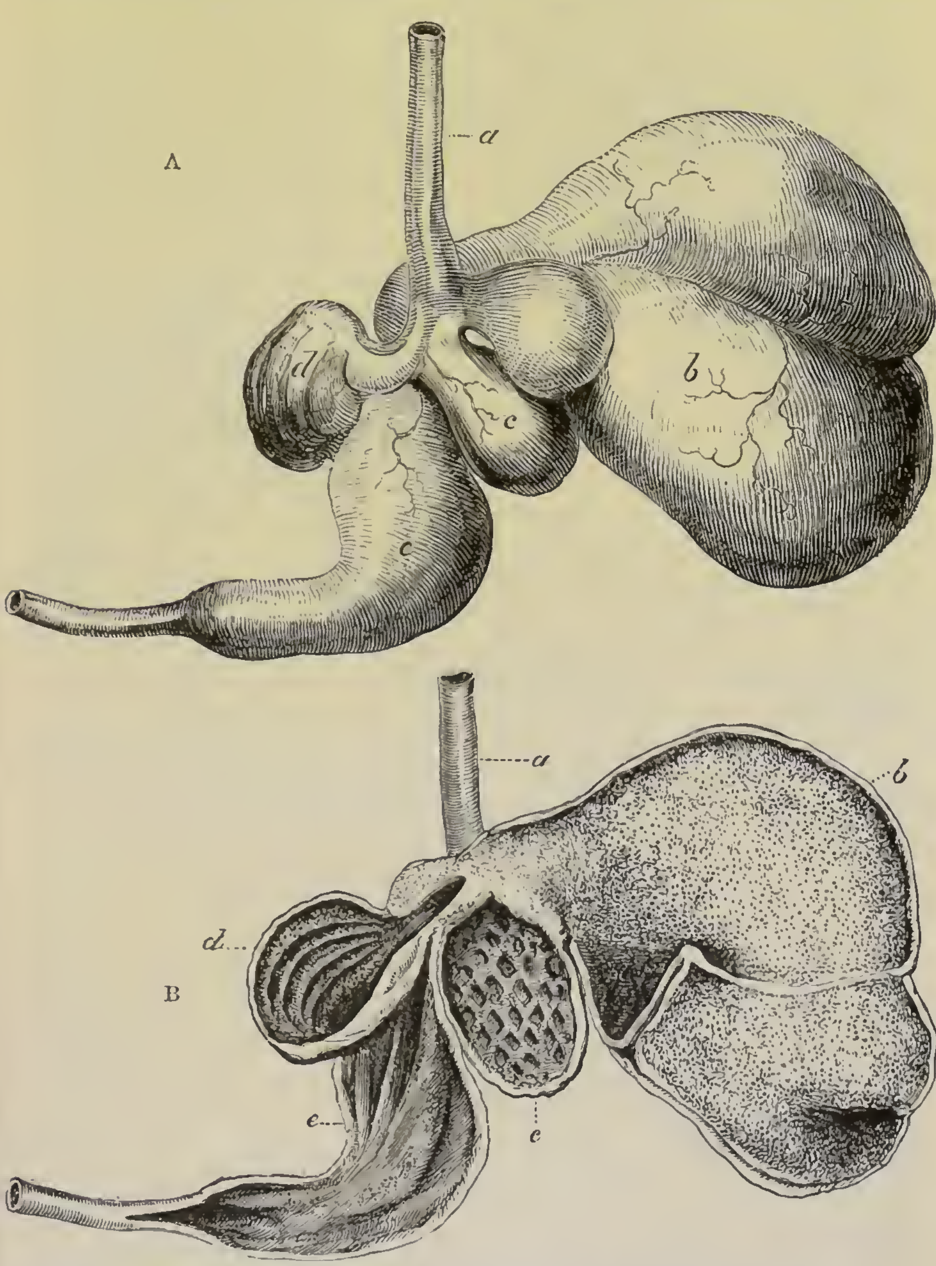


Fig. 493.—Stomach of a Ruminant, (A) from the exterior, and (B) with its cavities laid open: *a* Œsophagus; *b* Paunch; *c* Reticulum; *d* Manyplies; *e* Abomasum.

is effected. The stomach (fig. 493) is divided into four (rarely three) compartments, which are usually so distinct from one

another that they have generally been spoken of as so many separate stomachs. The gullet opens at a point situated between the first and second of these cavities or "stomachs." Of these the largest lies on the left side, and is called the "rumen" or "paunch" (fig. 493, *b*). This is a cavity of very large capacity, having its interior furnished with numerous hard papillæ or warts. It is the chamber into which the food is first received when it is swallowed, and here it is moistened and allowed to soak for some time. The second compartment, placed to the right of the paunch, is much smaller, and is known as the "reticulum" or "honeycomb-bag" (*c*). Its inner surface is reticulated, or is divided by ridges into a number of hexagonal or many-sided cells, somewhat resembling the cells of a honeycomb. The reticulum is small and globular, and it receives the food after it has lain a sufficient time in the paunch. The function of the reticulum, as usually believed, is to compress the soaked and moistened contents of the rumen into balls or pellets, which are then returned to the mouth by a reversed action of the muscles of the œsophagus, in order that they may undergo mastication. After having been thoroughly chewed and prepared for digestion, the food is swallowed for the second time, but on this occasion the food does not pass into the paunch, but is transmitted to the third compartment of the stomach, which is variously known as the "psalterium," "omasum," or (*Scotticè*) the "manyplies." The reason why the food takes a different course when swallowed for the second time to that followed when it is first swallowed, is this: The opening of the gullet into the stomach has its margins prolonged into two parallel folds or ridges, which form the bounding-walls of a deep groove running from the cardiac opening of the œsophagus to the psalterium, and which can be brought into apposition so as to convert the groove into a canal or tube. When the imperfectly masticated food is swallowed for the first time, it forces open the lips of this groove, and thus is transmitted directly into the paunch. On the other hand, when thoroughly chewed and swallowed for the second time, the now semi-liquid or pulpy food trickles along this groove into the psalterium, not being now sufficiently weighty or bulky to force apart the ridges which bound the groove. The mucous membrane lining the psalterium is thrown into numerous longitudinal folds (fig. 493, *d*), which are so close as to resemble the leaves of a book, and which serve to strain the food and keep back unmasticated fragments. The psalterium opens by a wide aperture into the fourth or pyloric compartment of the stomach, which is known as the "abomasum" (fig. 493, *e*).

The mucous membrane of this is thrown into a few longitudinal folds, and its walls are glandular, and secrete the gastric juice. It is, therefore, the digestive portion of the stomach, and it opens into the duodenum.

The dentition of the Ruminants presents peculiarities almost as great and as distinctive as those to be derived from the digestive system. In the typical Ruminants (*e.g.*, Oxen, Sheep, Antelopes) there are no incisor teeth in the upper jaw, their place being taken by a callous pad of hardened gum, against which the lower incisors impinge (fig. 494). There are also

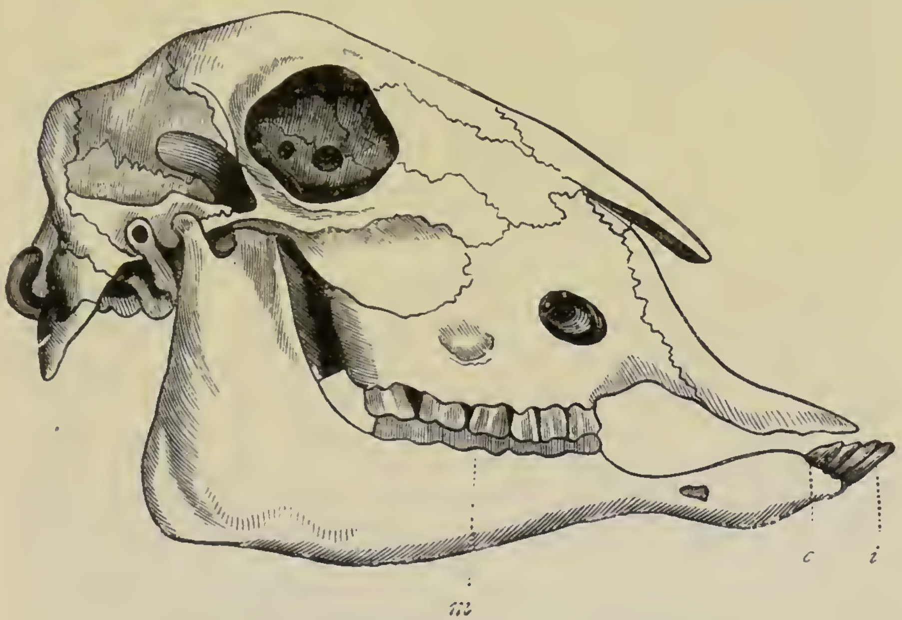


Fig. 494.—Skull of a hornless Sheep: *i* Incisors; *c* Canines; *m* Molars and præmolars. (After Owen.)

no upper canine teeth, and the only teeth in the upper jaw are six grinders on each side. In the front of the lower jaw is a continuous and uninterrupted series of eight teeth, of which the central six are incisors, and the outer ones are canines. The canines of the lower jaw of the typical Ruminants differ, however, from canine teeth generally, in the fact that they are placed in the same series as the incisors, which they altogether resemble in shape, size, and direction.

Behind this continuous series of eight teeth in the lower jaw, there is a vacant space, which is followed behind by six grinders on each side. The præmolars and molars are of the "selenodont" type (fig. 487), and have their grinding-surfaces marked respectively with one or two double crescents, the

convexities of which are turned inwards in the upper, and outwards in the lower teeth.

The dental formula, then, for a typical Ruminant animal is—

$$i\,\frac{0-0}{3-3};\ c\,\frac{0-0}{1-1};\ pm\,\frac{3-3}{3-3};\ m\,\frac{3-3}{3-3} = 32.$$

The departures from this typical formula occur in the *Camelidæ*, the *Tragulidæ*, and in some of the Deer. Most of the Deer conform in their dentition to the above formula, but a few forms (*e.g.*, the Muntjak) have canine teeth in the upper jaw. These upper canines, however, are mostly confined to the males; and if they occur in the females, they are of a small size. The dentition of the *Camelidæ* (Camels and Llamas) is still more aberrant, there being two pointed upper incisors and upper canines as well. The lower canines also are more pointed and stand more erect than the lower incisors, and are slightly separated from them, so that they are easily recognisable.

The group of the *Ruminantia* includes the groups of the *Camelidæ* (Camels and Llamas), the *Tragulidæ* (Chevrotains), the *Cervidæ* (Deer), the *Camelopardalidæ* (Giraffe), and the *Cavicornia* (Oxen, Sheep, Goats, Antelopes).

1. *Camelidæ* (*Tylopoda*).—The Camels and Llamas constitute in many respects an aberrant group of the *Ruminantia*, especially as regards their dentition and the conformation of the feet. The upper jaw (fig. 495) carries three teeth on each

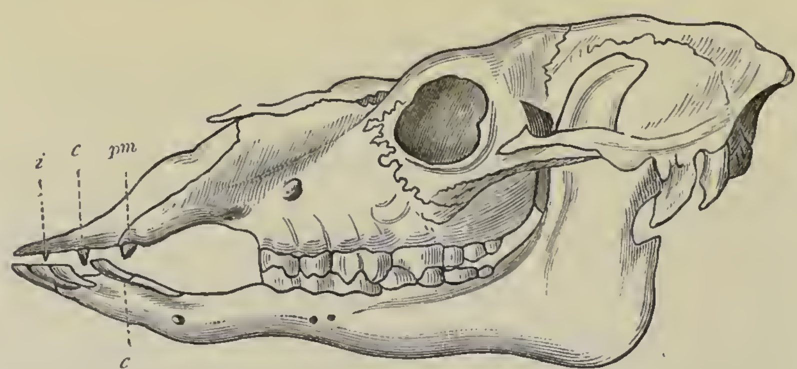


Fig. 495.—Side view of the skull of *Camelus bactrianus*: *i* Upper incisor; *c c* Canines; *pm* Isolated præmolar. (After Giebel.)

side in front, separated by slight intervals. The most anterior of these is a conical incisor; the central one is a canine, and the hindmost is the first præmolar, which is separated by a wide gap from the rest of the molar series, and is pointed in

form. In the lower jaw there is also a canine, placed a little behind the incisors, and a detached laniariform præmolar (the latter sometimes absent). In the Llamas these isolated præmolars do not exist. Each foot (fig. 485, 6) terminates in two toes, which are provided with imperfect nail-like hoofs, covering no more than the upper surface of each toe. The second and fifth toes, which are mostly present in the Ruminants, are here altogether wanting, and the animal walks upon the hinder surfaces of the toes, which are directed downwards, and are protected by pads of callous horny integument. The stomach is peculiar in the fact that the manyplies is absent, and the paunch has its walls hollowed out into deep water-cells, occupying two special tracts of its internal surface. As regards their further characters, the head of all the *Camelidæ* is destitute of horns in both sexes; the nostrils can be closed at the will of the animal; the upper lip is hairy and partially cleft; and the red blood-corpuscles are oval.

The family of the *Camelidæ* is represented in the Old World by the Camels (*Camelus*), and in South America by the Llamas and Alpacas (*Auchenia*). There is also an extensive series of Tertiary forms, one of which (viz., *Protolabis*) is specially interesting as possessing the full number of upper incisors, namely, three on each side of the jaw.

The true Camels are peculiar to Asia and Africa, and two species are known, distinguished from one another by the possession of a double or single adipose hump on the back; but neither of these are truly wild. The African or Arabian Camel (*Camelus dromedarius*) is often called the Dromedary, and has only one hump on its back. The two toes are united together by the callous sole; and the chest, shoulders, and knees are furnished with callous pads, upon which the animal rests when lying down. The hump is almost entirely composed of fat, and appears to act as a kind of reserve supply of food, as it is noticed to diminish much in size upon long journeys. The Camel can likewise support a very prolonged privation of water, as the paunch is furnished with large cells, which the animal fills when it has access to water, to be made use of subsequently as occasion may require. The structure of the Camel adapts it admirably for locomotion in the sandy deserts of Arabia and Africa; and as it is patient and enduring, it is almost exclusively employed as a beast of burden in the countries in which it occurs.

The Bactrian Camel (*C. bactrianus*) is distinguished by the possession of two humps; but in other respects it does not differ from the Dromedary. It is found in Turkestan, Persia, Mongolia, and Thibet, extending north to Lake Baikal, and eastwards to Pekin. The two species are said to breed together, and the hybrid offspring is stated to be occasionally fertile.

The place of the Camels is taken in the New World by the Llama and Alpaca, with their respective wild forms. These animals form the genus *Auchenia*, and are in many respects similar to the true Camels. They are distinguished, however, by having no hump upon the back, and by the fact that the two toes are not conjoined and supported by a callous

pad, as in the Camels, but are separate, with separate pads, and with strong curved nails. The neck is long and the head comparatively small, whilst the upper lip is mobile and deeply cleft vertically. The Llamas are chiefly found in Peru and Chili. They live in flocks in mountainous regions, and are much smaller than the Camels in size. The true Llama is kept as a domesticated animal, and used as a beast of burden, its wild form being known as the "Guanaco." The Alpaca is still smaller than the Llama, and is not very unlike a sheep, having a long woolly coat. It is partially domesticated, and the wool is largely imported into Europe. Its wild form is the so-called "Vicuna."

As regards their *distribution in time*, the *Camelidæ* are first represented in the Miocene deposits of North America (*Poëbrotherium*, &c.).

2. *Tragulidæ.*—This group comprises certain small Ruminants, the so-called "Chevrotains" (*Tragulus*), which have been sometimes associated with the Musk-deer (*Moschus*). The researches of Milne-Edwards and Flower have, however, shown that the relationships of *Moschus* are with the *Cervidæ* or Deer proper, and that the Chevrotains constitute a special group of Ruminants.

The *Tragulidæ* are characterised by the total absence of horns in both sexes, and by the presence of canines in both jaws, those in the upper jaw being in the form of tusks in the males (fig. 496), but much smaller in the females. The third

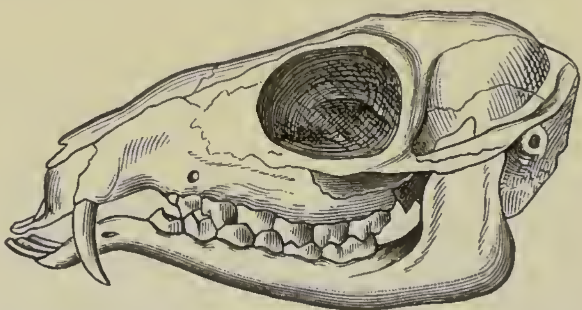


Fig. 496.—Side view of the skull of *Tragulus javanicus*. (After Giebel.)

stomach, or "psalterium," is wanting, and the placenta is diffuse. The Chevrotains are peculiar in the fact that the second and fifth digits, though small, are complete (fig. 485, 2 and 3), and also in the fact that the metacarpals and metatarsals of the functional toes (the 3d and 4th) either do not unite to form a cannon-bone till late in life, or remain (as in *Hyomoschus*) permanently separate.

This family includes at the present day only the *Hyomoschus* of Western Africa, and some four or five species of *Tragulus* from the Indian province. The best known are the *Tra-*

gulus javanicus, or "Napu" of Java, and the *T. meminna* of India. They are all very small and elegant animals, and, though commonly called "Musk-deer," they have no musk-gland.

As regards their *distribution in time*, the earliest forms of the *Tragulidæ* (*Amphitragulus* and *Dremotherium*) appear in the Miocene period.

3. *Cervidæ.*—This family is of much greater importance than that of the *Tragulidæ*, including as it does all the true Deer. They are distinguished from the other Ruminants chiefly by the nature of the horns, which are wanting in the genera *Moschus*, *Hydropotes*, and *Lophotragus*. With the single exception of the Reindeer, these appendages are confined to the males amongst the *Cervidæ*, and do not occur in the females. They do not consist, as in the succeeding group, of a hollow sheath of horn surrounding a central bony core, nor are they permanently retained by the animal. On the other hand, the horns—or, as they are more properly called, the *antlers*—of the *Cervidæ* are deciduous, and are solid. They are bony throughout, and are usually more or less branched (fig. 498), and they are annually shed and annually reproduced at the breeding season. They increase in size and in the number of branches every time they are reproduced, until in the old males they may attain an enormous size. The antlers are carried upon the frontal bone, and are produced by a process not at all unlike that by which injuries of osseous structures are made good. At first, the antlers are covered with a sensitive hairy skin or "velvet"; but when the horn is fully formed, there is produced a bony ridge or "burr" a little above its base, separating the horn into a basal stem, or "pedicel," and a distal portion, or "beam." The pressure of the "burr" upon the vessels which supply the velvet with blood leads to their gradual obliteration, the skin then dying and peeling off, thus leaving the horn as a naked bony process (fig. 497).

When fully developed, the antlers of the Deer consist of a main stem or "beam," carrying one or more branches or "tynes." In the second year after birth, when the antlers are first produced, and in a few Deer throughout life, the antler consists only of the "beam," and is dagger-shaped and unbranched, the animal being known now as a "brocket." In the horns of the next year, the antler develops a basal branch or "brow-tyne." In the horns of the fourth year, the beam above the brow-tyne becomes bifurcated, the divisions thus produced ("tres-tyne" and "royal tyne") remaining simple in some cases, or in other cases undergoing further subdivision. The differences in the horns of different kinds of Deer depend principally upon the extent to which this subdivision of the beam, as regards one or both of its primary divisions, is carried on; and the following are the principal types of antlers:—

(A.) *Rusine type.*—The brow-tyne simple, the beam simply divided (fig.

498, A). This form of antler occurs in the Sambur Deer (*Rusa Aristotelis*) and in the Axis Deer of India.

(B.) *Rucervine type.*—The two primary divisions of the beam above the

Fig. 497.—Side view of the skull of the Roebuck (*Capreolus capræa*). (After Giebel.)

brow-tyne again bifurcated, and both divisions approximately equal, as in the *Rucervus Schomburgki* of Siam (fig. 498, B). In a modification of this type, the royal tyne is reduced in size (fig. 498, C), and the tres-tyne is large; while in a still more extreme type, the royal tyne is reduced to a mere snag.

(C.) *Elaphine type.*—Brow-tyne reduplicated (by the presence of a "bez-tyne"); the royal tyne large and divided. This type occurs in the Red-deer (*Cervus elaphus*, fig. 498, F and G). In the "sub-elaphine" type (as in the *Cervus sika* of Japan), the brow-tyne is simple.

(D.) *Capreoline type.*—The beam dividing into a short anterior and a longer posterior branch, the latter, when fully developed, again bifurcated at its extremity (fig. 498, D). This type of antler occurs in the Roebuck (*Capreolus capræa*).

(E.) *Type of the Muntjak.*—Antler supported upon a long osseous pedicle arising from the frontal bone; a short brow-tyne; the beam undivided (fig. 498, E). Occurs only in the Muntjak (*Cervulus muntjak*).

Of the other characters of the *Cervidæ*, it may be noted that upper canines are occasionally developed (Muntjak, Musk-deer), and that the second and fifth digits are present, though rudimentary (fig. 485, 4). The lachrymal bone exhibits a deep antorbital pit, which lodges a peculiar gland (the "larmier"), which secrets a strongly odorous waxy substance. In many cases, also, there is a larger or smaller vacuity between the frontal, nasal, lachrymal, and maxillary bones.

The *Cervidæ* are very generally distributed, but no member of the group has hitherto been discovered in either Australia or South Africa, their place in the latter continent seeming to be taken by the nearly-allied Antelopes (distinguished by their

hollow horns). Africa, in fact, has no Deer except the Barbary Deer alone, and this occurs north of the Sahara only.

Very many species of *Cervidæ* are known, and it is not possible to allude to more than a few of the more familiar and important forms. Three species occur in Britain—namely, the Roebuck, Red-deer, and Fallow-deer, the last not being truly indigenous. The Roebuck (*Capreolus capræa*) was once very generally distributed over Britain, but is almost confined to the wilder parts of Scotland at the present day. It is of small size, and ranges over Northern Europe and Asia. The Red-deer or Stag (*Cervus elaphus*) is a

Fig. 498.—A, Antler of the "Rusine" type (Sambur Deer); B, Antler of the "Rucervine" type (*Rucervus Schomburgki*); C, Modified Rucervine type of antler (*Rucervus Duvaucelli*), in which the "royal" tyne is reduced in size; D, Antler of the "Capreoline" type (*Capreolus capræa*); E, Antler of the Muntjak (*Cervulus muntjak*); F, Antler of the Red-deer (*Cervus elaphus*) of the second year; G, Antler of the full-grown Red-deer, showing the "elaphine" type.

much larger species, with well-developed spreading antlers. The Red-deer of Britain is represented in North America by a still larger species, known as the Wapiti (*Cervus canadensis*).

The third British species is the Fallow-deer (*Dama vulgaris*), characterised by the fact that the antlers are palmated—that is, dilated towards their extremities. It is not indigenous to Britain, and its native habitat is apparently the shores of the Mediterranean. Allied to the Fallow-deer is a gigantic extinct species, the *Megaceros hibernicus*, which inhabited Ireland, the Isle of Man, Scotland, and probably the greater part of Europe, up to a comparatively modern date, probably having survived into the human period. It is often, but incorrectly, spoken of as the Irish "Elk," but it is really a genuine Stag. The animal was of very great size,

and was furnished with enormous spreading and palmate antlers, which measure from ten to twelve feet between the tips.

Of all the Deer, the largest living form is the true Elk (*Alces palmatus*), which is generally distributed over the northern parts of Europe, Asia, and America, being often spoken of as the Moose. The antlers in the Elk are of a very large size, and are very broad, terminating in a series of points along their outer edges.

The only completely domesticated member of the *Cervidæ* is the Reindeer (*Cervus tarandus*), which is remarkable for the fact that the female is furnished with antlers similar to, but smaller than, those of the males. At the present day, the Reindeer (if the Caribou be regarded as distinct) is exclusively confined to the extreme north of Europe and Asia, abounding especially in Lapland. Remains, however, of the Reindeer are known to occur over the greater part of Europe, extending as far south, at any rate, as the Alps, and occurring also in Britain. From this fact, taken along with many others, the existence of an extremely cold climate over the greater part of Europe at a comparatively recent period may be safely inferred. The Reindeer lives chiefly upon moss and a peculiar kind of lichen, and they are extensively used by the Laplanders both as beasts of burden and as supplying food. The "Caribou" of North America, if not absolutely identical with the Reindeer, would seem to be, at most, a well-marked variety of it.

The so-called "Brockets" are small Deer, in which the horns are simple and stiletto-shaped, without tynes. They are natives of South America. The Muntjaks (*Cervulus*) inhabit India, Burmah, China, and the Indian Archipelago, and have the horns supported upon long bony pedicles springing from the frontal bones, while the males have large upper canines.

The true Musk-deer (*Moschus moschiferus*) possess no horns, and the males have a musk-gland. There are canine teeth in both jaws, and the upper canines of the males have the form of long tusks. The Musk-deer are elegant little animals, which agree with the typical Deer in the fact that they have spotted young, and that the placenta is cotyledonary, whilst they depart from the ordinary cervine type in the absence of antlers. They inhabit Central Asia.

The curious Water-deer (*Hydropotes*) of China is related to *Moschus*, and also has no horns. Another curious Chinese form is the *Elaphurus*, in which there is a long tufted tail, and the antlers, in place of an anterior basal branch, possess a long posterior branch, the end of which is dilated and prolonged into several short points.

As regards their *distribution in time*, the earliest remains of *Cervidæ* appear in the Miocene (*Dorcatherium*, *Dicroceros*, &c.). *Cervus* itself appears in the Upper Miocene, and of the same age is the genus *Amphimoschus*, related to the living Musk-deer.

4. *Camelopardalidæ*.—This family includes only a single living animal—the *Camelopardalis giraffa*, or Giraffe—sometimes called the Camelopard, from the fact that the skin is spotted like that of the Leopard, whilst the neck is long, and gives it some distant resemblance to a Camel. There are no upper canines in the Giraffe, and both sexes possess two small frontal horns, which, however, are persistent, and remain permanently covered by a hairy skin, terminated by a tuft of long

stiff bristles. These are not mere out-growths of the frontals, but are independent ossifications placed on the sutures between the frontal and parietal bones. There is also a central horn, if it may be so called, which is of the nature of an epiphysis, and is placed upon the sagittal suture. It becomes early anchylosed with the skull, as do ultimately the other two horns. The neck is of extraordinary length, but, nevertheless, consists of no more than the normal seven cervical vertebræ. The fore-legs appear to be much longer than the hind-legs, and all are terminated by two toes each, the second and fifth digits being altogether wanting. The tongue is very long and movable, and is employed in stripping leaves off the trees. The Giraffe is the largest of all the Ruminants, measuring as much as from fifteen to eighteen feet in height. It is a harmless and inoffensive animal, but defends itself very effectually, if attacked, by kicking. It is found in Africa, south of the Sahara.

Remains of gigantic Ruminants allied to the Giraffe have been found in the later Tertiary deposits of France and Greece (*Helladotherium*); but the *Sivatherium*, sometimes referred to this family, appears to have been more nearly allied to the true Antelopes.

5. *Cavicornia.*—The last family of the Ruminants is that of the *Cavicornia*, comprising the Oxen, Sheep, Goats, and Antelopes. This family includes the most typical Ruminants, and those of most importance to man. The upper jaw in all the *Cavicornia* is wholly destitute of incisors and canines, the place of which is taken by the hardened gum, against which the lower incisors bite. There are six incisors and two canines in the lower jaw, placed in a continuous series, and the molars are separated by a wide gap from the canines. Both sexes have horns, or the males only may be horned, but in either case these appendages are very different to the "antlers" of the *Cervidæ.* The horns, namely, are persistent, instead of being deciduous, and each consists of a bony process of the frontal bone—or "horn-core"—covered by a sheath of horn (fig. 499). In the Prong-buck (*Antilocapra*), however, the *sheath* of the horn is shed annually. The feet are cleft, but are mostly furnished with accessory hoofs (the rudiments of the second and fifth digits) placed on the back of the foot.

The *Cavicornia* comprise the three families of the *Antilopidæ*, *Ovidæ*, and *Bovidæ.* The Antelopes form an extremely large section, with very many species. They are characterised by their slender deer-like form, their long and slender legs, and their simple cylindrical, annulated or twisted horns, which are sometimes confined to the males, but often occur in the females

as well (fig. 500). They possess the same sub-orbital glands ("larmiers") as have been mentioned as occurring in the *Cervidæ;* and they have also two odiferous glands on the groin, the openings of which are known as the "inguinal

Fig. 499.—Skull of the Cape Buffalo (*Bubalus caffer*) viewed from above, showing the horn-cores. (After Cuvier.)

pores." The second and fifth digits are usually, but not always present, as rudiments, represented by two small accessory hoofs on the back of the foot.

The Antelopes form a very large and widely distributed family, being especially numerous, both in individuals and species, in Africa, in which country they appear to take the place of the true Deer (only one species of Deer being indigenous to Africa). Amongst the better-known African species of Antelopes are the Springbok, Hartebeest, Gnu, Eland, and Gazelle. The only European Antelopes are the Chamois (*Rupicapra tragus*), which inhabits the Alps and other mountain-ranges of southern Europe, and the Saiga of eastern Europe. Amongst the more remarkable Antelopes may be mentioned the Prong-buck (*Antilocapra americana*) of N. America, in which there are no accessory hoofs, lachrymal sinuses, or inguinal pores; the females have very small horns, and the horns of the male have a snag or branch in front. The horn-core, however, is conical, and does not extend above the snag. The horns are also very remarkable for the fact that their sheath is annually shed, and annually reproduced. Another curious form is the Chickara (*A. quadricornis*) of India, in which the females are hornless, but the males have four horns.

The Sheep and Goats (*Ovidæ*) have mostly horns in both

sexes, and the horns are generally curved, compressed, and turned more or less backwards. The body is heavier, and the legs shorter and stouter, than in the true Antelopes.

Fig. 500.— Head of the Koodoo (*Strepsiceros koodoo*).

The Goats (*Capra*) are distinguished from the Sheep by their more slender limbs, long and oblique nostrils, and flattened arched horns. The throat is furnished with long hair, forming a beard, and this appendage may be confined to the males or may be present in both sexes. The domestic Goat is believed to be descended from the "Paseng" (*Capra ægagrus*) of the Caucasus and Persia. One species of *Ibex* (*I. alpinus*) inhabits the high ranges of Central and Eastern Europe, but is becoming gradually rarer.

The Sheep have generally shorter and stouter limbs than the Goats, a beard being absent, and the horns being spirally twisted. Horns are usually present in both sexes, but are absent in the females of some breeds of the domestic Sheep (*Ovis aries*). Some of the breeds of the domestic Sheep, and more particularly the smaller short-tailed breeds, with crescent-shaped horns, seem to be descended from the "Moufflon" (*Ovis musimon*), which is still found wild in Corsica and Sardinia. In the Thian-Shan Mountains, above heights of 9000 feet, is found the *Ovis poli*, distinguished by the immense, laterally-directed, spiral horns. The *Ovis Ammon* of Thibet is long-legged, and has large horns which describe a nearly complete circle. The genus *Ovis* is represented in North America by the "Bighorn" (*O. montana*) of the Rocky Mountains.

The true Oxen (*Bovidæ*) are distinguished by having simply rounded horns, which are not twisted in a spiral manner, and are usually directed more or less outwards. Most of the Oxen admit of being more or less completely domesticated, and some of them are amongst the most useful of animals, both as beasts of burden and as supplying food.

Of the numerous forms of Oxen, the following are the more remarkable types :—

(*a.*) The numerous domestic varieties of Oxen may be grouped together

under the common name of *Bos taurus*. The nearest approach to British Wild Oxen are the well-known "Chillingham Cattle," of which two herds still exist. They are white in colour, with a black muzzle, the horns white, tipped with black. The domestic breeds of European Oxen seem for the most part to have descended from one or other of two now extinct types. One of these is the "Urus" (*Bos primigenius*), which existed in Germany when it was invaded by the Romans; and the other is the British Short-horn" (*Bos longifrons*) of Owen. Of the *Bos taurus* type are the Oxen known as the "Gour," the "Gayal," and the "Banteng," which are found in India and the Indian Archipelago, and have their horns bent at first outwards and then upwards.

(*b*.) The Humped Cattle (*Bibos*) of the Oriental province are distinguished by possessing a fatty hump over the withers. A well-known form is the Zebu (*B. indicus*), which is often hornless. The Humped Cattle are known from Egyptian monuments to have been domesticated from an extremely early period, but their wild form is unknown.

(*c*.) The Bisons are distinguished by having a shaggy mane, a hump on the shoulders, a very large head, and a tufted tail. The European Bison or "Aurochs" (*Bison europæus*), formerly very widely distributed, now only occurs in one of the forests of Lithuania, where it is specially protected; but it is said to be found also in the Caucasus. The American Bison or "Buffalo" (*Bison americanus*), once extraordinarily abundant in the western United States and Canada, is also now almost extinct.

(*d*.) The true Buffaloes (*Bubalus*) have large horns, triangular in section, turned outwards and backwards, and often confluent at their bases. The common Buffalo (*Bubalus bubalis*) is found in Southern Europe and North Africa; and the "Arnee" of India is a long-horned variety of it. The Cape Buffalo (*Bubalus caffer*) has short horns, with greatly expanded bases, and ranges over Africa south of the equator.

(*e*.) The "Yak" (*Poëphagus grunniens*) represents a quite peculiar type of Oxen, distinguished by the possession of a long silky tail and of a fringe of long hair along the shoulders, flanks, and thighs. It inhabits the table-lands of Thibet.

(*f*.) Lastly, a remarkable type of the Oxen is presented by the Musk-ox (*Ovibos moschatus*), which is in some respects intermediate between the Oxen and the Sheep, and which is by high authorities regarded as properly referable to the latter. The body of the Musk-ox is massive, with very short legs and a short tail; the hair long; the nose hairy; and the horns of the males very wide, bent downwards along the side of the head, and then bent outwards and upwards. At present the Musk-ox is confined to Arctic America north of latitude 60°; but it formerly ranged over Northern Asia, as well as over Northern and Central Europe.

As regards their *distribution in time*, the Cavicorn Ruminants are apparently a modern type, the earliest forms appearing in the Miocene or in the beginning of the Pliocene period. Among the more remarkable extinct types may be mentioned the gigantic four-horned Antelopes from the Pliocene deposits of India, upon which the genus *Sivatherium* has been founded.

CHAPTER LXIX.

DINOCERATA, TILLODONTIA, AND TOXODONTIA.

ORDER VII. DINOCERATA. — This order comprises certain extraordinary extinct Mammals from the Eocene of North America, which are regarded by Prof. Cope as an aberrant group of *Ungulates*, whilst Prof. Marsh considers them as a distinct order intermediate between the *Perissodactyle Ungulates* and the *Proboscidea*.

The members of this order are all of gigantic dimensions, and of massive construction. *Both the hind-feet and fore-feet possessed five well-developed toes. The nasal bones were elongated, and do not seem to have supported a proboscis. The cranium carries three pairs of horn-cores, which were probably enveloped in horny sheaths. There are no upper incisors, and the upper canines have the form of long tusks directed downwards.* (These characters are taken from *Dinoceras*, the best-known genus of the group.) The order is distinguished from the *Proboscidea* by the absence of upper incisors, the presence of canines, the possession of three pairs of horn-cores, and the absence of a proboscis.

In *Dinoceras* itself, which may be taken as the type of the group, we have a large animal equal in dimensions to the living Elephants, which it resembles also in the osteology of its limbs, in most essential respects. It is in the skull (fig. 501) and dentition, however, that the most striking peculiarities of *Dinoceras* are to be found. As regards the dentition, the front of the upper jaw was destitute of incisors, and probably carried a palatine pad, but there were two very large canines in the form of tusks directed perpendicularly downwards; and there was also a series of six small grinders on each side. In the lower jaw are six incisors, small canines, and twelve præmolars and molars, six on each side. The dental formula is thus—

$$i\,\frac{0-0}{3-3};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{3-3}{3-3};\quad m\,\frac{3-3}{3-3}=34.$$

Superiorly each maxillary bone carried a well-developed process, probably of the nature of a horn-core. The nasals support two similar but smaller horn-cores; and the frontals and parietals carried posteriorly two larger bony projections, most probably also of the nature of horn-cores. The animal thus

possessed three pairs of horns, one carried by the upper jaw-bones, one by the nasals, and one by the frontal bones; though it is possible that some or all of these cores were simply covered by a callous integument. The nasal bones are long,

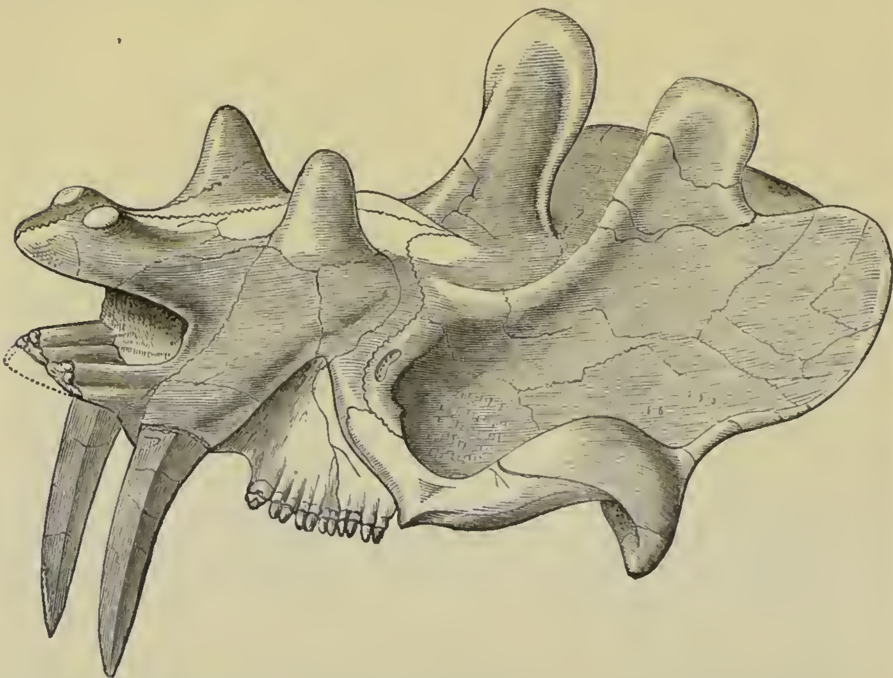


Fig. 501.—Skull of *Dinoceras mirabile*, after Marsh. From the Eocene Tertiary.

and there is no evidence of any proboscis; but there are peculiar prænasal ossifications. The limbs are short, the fore-legs shorter than the hind-legs; and the femur was not provided with a third trochanter. The tail is short and slender.

As regards the mental powers of *Dinoceras*, Prof. Marsh remarks: "The brain-cavity of *Dinoceras* is perhaps the most remarkable feature in this remarkable genus. It proves conclusively that the brain was proportionately smaller than in any other known Mammal, recent or fossil, and even less than in some reptiles. It is, in fact, the most reptilian brain in any known Mammal. In *D. mirabile*, the entire brain was actually so diminutive that it could apparently have been drawn through the neural canal of all the præsacral vertebræ, certainly through the cervicals and lumbars."

The three genera which are included amongst the *Dinocerata* by Marsh are *Dinoceras*, *Tinoceras*, and *Uintatherium*. All the remains of this singular group which have hitherto been brought to light, are from the Eocene rocks of North America.

ORDER VIII. TILLODONTIA.—This order has been estab-

lished by Prof. Marsh for the reception of some singular Mammals from the Eocene Tertiary of the United States. The following are the characters of the order, so far as published: *The molar teeth have grinding crowns, as in Ungulates, and may have distinct roots, or may grow from permanent pulps; small canines are present in both jaws; and each jaw carries two long scalpriform incisors, resembling those of Rodents in form and in growing from persistent pulps. The feet are plantigrade and pentadactyle, and the digits were apparently unguiculate. The femur has a third trochanter, and the radius and ulna and tibia and fibula are distinct bones.*

The order includes two distinct families,—one, the *Tillotheridæ*, having molar teeth with distinct roots; whilst the other, *Stylinodontidæ*, possessed rootless molars, which grew from persistent pulps. All the known forms of the order are from the Eocene Tertiary, and the typical species seem to have been from one-half to two-thirds of the size of the Tapir.

The type-genus of the order is *Tillotherium*, which presents a remarkable combination of the characters of the *Ungulata*, *Rodentia*, and *Carnivora*. The general form of the skeleton most closely resembles that of the Carnivores, the skull being

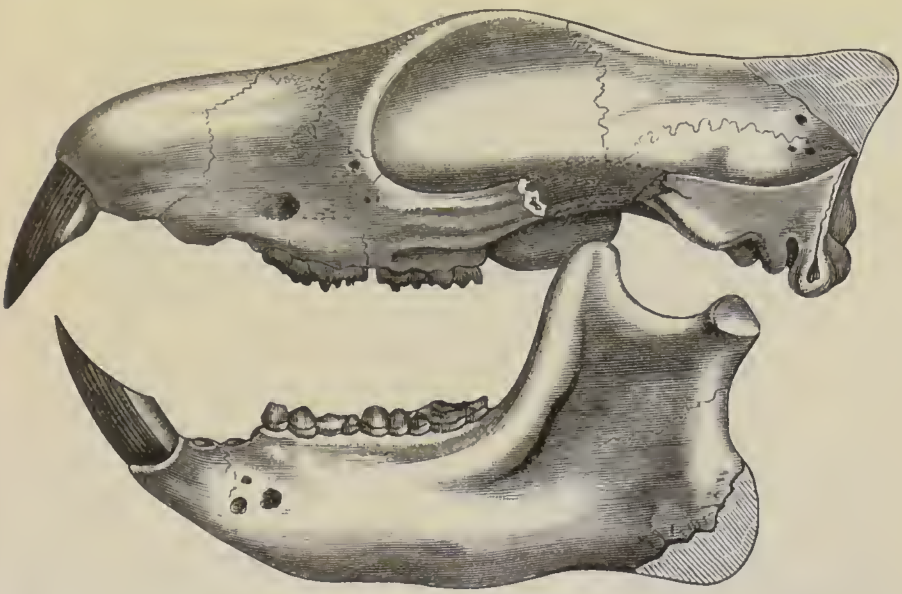


Fig. 502.—*Tillodontia.* Side view of the skull of *Tillotherium fodiens*, with the lower jaw displaced downwards, one-fourth of the natural size. (After Marsh.)

like that of the Bears in many respects, whilst the feet are five-toed, with the whole sole applied to the ground, and having ungual phalanges similar to those of the *Ursidæ*. The brain-

cavity is of small size, and the cerebral hemispheres did not extend over the cerebellum or the olfactory lobes. The orbits are not complete, but open into the temporal fossæ. The præmolars and molars have grinding crowns, the canines are of small size, and the præmaxillæ carried a pair of large scalpriform incisors (fig. 502), which resemble those of the Rodents in having chisel-shaped crowns, and in growing throughout the life of the animal. As in Rodents, there is a corresponding pair of scalpriform incisors in the lower jaw. The dental formula is—

$$i\,\frac{1-1}{1-1};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{2-2};\ m\,\frac{3-3}{3-3} = 30.$$

ORDER IX. TOXODONTIA.—This order includes certain large extinct Mammals from the later Tertiary deposits of South America, the true systematic position of which is still very doubtful, since they present affinities to the *Ungulata*, the Rodents, and the Edentates. The skull is massive and the dentition is very peculiar. The molars and præmolars are bent so as to be strongly convex outwards and concave inwards, with flat grinding-surfaces (fig. 503), and presenting the pecu-

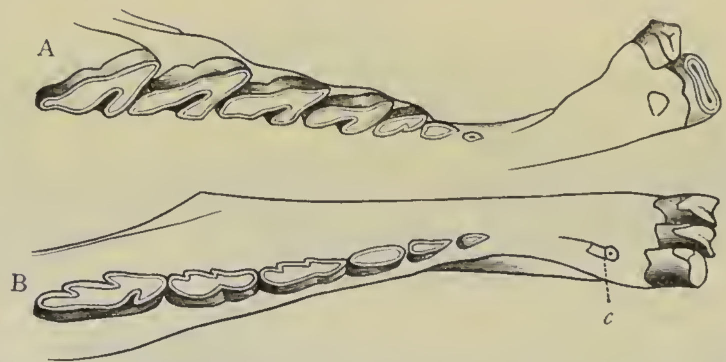


Fig. 503.—A, Right upper jaw of *Toxodon Burmeisteri*, and (B) left lower jaw of the same; *c* Lower canine. (After Burmeister.) Greatly reduced in size.

liarity that they are rootless and grow from persistent pulps. Canines are present in the lower jaw, but are of very small size (fig. 503, *c*), and are placed in the interval between the incisors and præmolars. In the upper jaw only the sockets for the canines are left. There are four upper and six lower incisors, which are separated by a wide diastema from the præmolars. The dental formula is—

$$i\,\frac{2-2}{3-3};\ c\,\frac{0-0}{1-1};\ pm\,\frac{4-4}{3-3};\ m\,\frac{3-3}{3-3} = 38.$$

There is no third trochanter to the femur, but the structure of the manus and pes is quite unknown.

The only known genera are *Toxodon* and *Nesodon*.

CHAPTER LXX.

HYRACOIDEA AND PROBOSCIDEA.

Order X. Hyracoidea.—This is a very small order which has been constituted by Huxley for the reception of two or three little animals, which make up the single genus *Hyrax*. These have been usually placed in the immediate neighbourhood of the Rhinoceroses, to which they have some decided affinities, and they are still retained by Owen in the section of the Perissodactyle Ungulates.

The order is distinguished by the following characters: *There are no canine teeth, and the incisors of the upper jaw are*

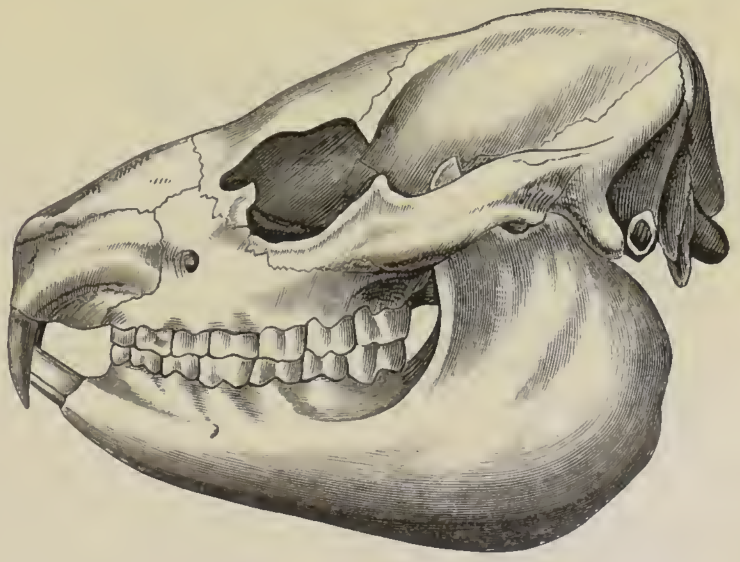


Fig. 504.—Skull of *Hyrax*. (After Cuvier.)

long and curved, and grow from permanent pulps, as they do in the Rodents (such as the Beaver, Rat, &c.). The lower incisors are directed forwards. The molar teeth are singularly like those of the Rhinoceros. The manus has four functional digits, the pollex being rudimentary; and the pes is tridactylous. All the

toes have rounded hoof-like nails, with the exception of the inner digit of the pes, which has an obliquely curved nail. Clavicles are wanting; the placenta is deciduate and zonary.

The species of *Hyrax* are small, rabbit-like, plantigrade animals, in which the body is covered with hair, the nose and ears are short, the upper lip is cleft, and the tail is represented by a mere tubercle. There are four upper incisors which resemble those of Rodents in growing throughout the life of the animal, but which are triangular and pointed, instead of having the form of quadrangular prisms, as they have in the latter. The outer pair of incisors fall out early; the condyle of the mandible is transversely elongated; and the lower incisors are directed forwards. The dental formula is—

$$i\,\frac{2-2}{2-2};\ c\,\frac{0-0}{0-0};\ pm\,\frac{4-4}{4-4};\ m\,\frac{3-3}{3-3}=36.$$

Several species of *Hyrax* are known, but they resemble one

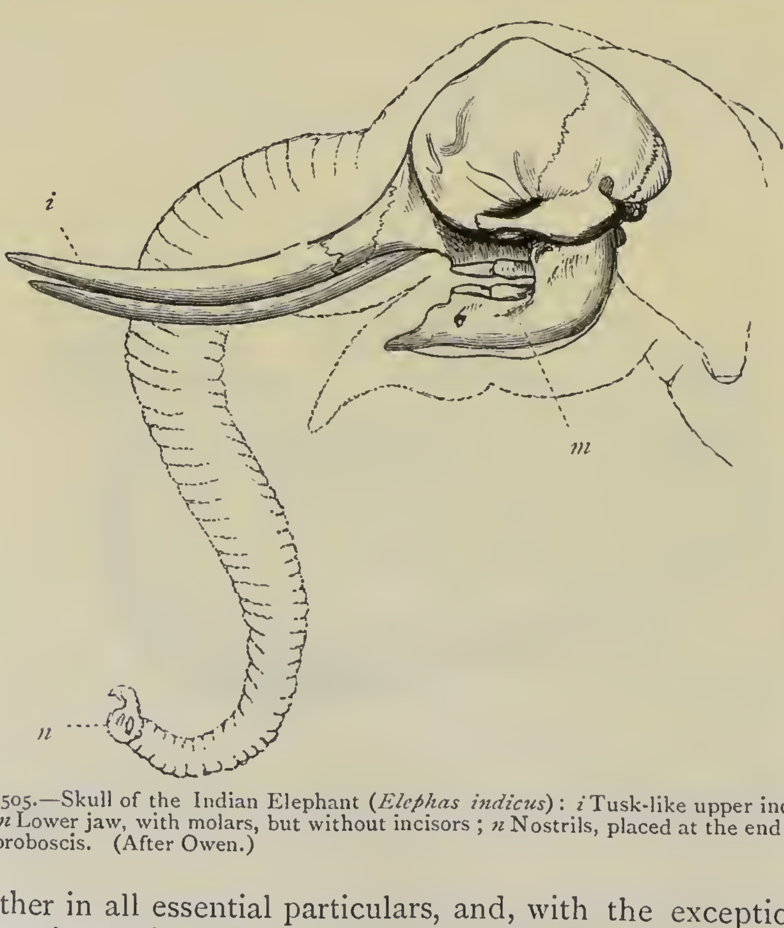


Fig. 505.—Skull of the Indian Elephant (*Elephas indicus*): *i* Tusk-like upper incisors; *m* Lower jaw, with molars, but without incisors; *n* Nostrils, placed at the end of the proboscis. (After Owen.)

another in all essential particulars, and, with the exception of *H. syriacus*, they are exclusively confined to Africa. They

are all gregarious little animals, living in holes of the rocks, and capable of domestication. The "coney" of Scripture is believed to be the *Hyrax syriacus*, which occurs in the rocky parts of Syria and Palestine. Another species—the *Hyrax capensis*, or "Klipdas" ("badger of the cliffs")—occurs commonly in South Africa, and is known by the colonists as the "badger."

No fossil remains have as yet been discovered which can with certainty be referred to this order.

ORDER XI. PROBOSCIDEA.—The eleventh order of Mammals is that of the *Proboscidea*, comprising no other living animals except the Elephants, but including also the extinct genera *Mastodon* and *Deinotherium*.

The *Proboscidea* are characterised by being *large terrestrial Mammals, with massive bodies, the skin thick and sparsely haired. The nose is prolonged into a cylindrical "trunk" or "proboscis," at the extremity of which the nostrils are situated. The feet are five-toed, and the extremities of the digits (some or all) are incased in hoofs. In the living forms there are no lower incisors, but there are two upper incisors, which grow from permanent pulps, and constitute long "tusks." Canines are entirely absent in both jaws; and the molar teeth are few in number, large, and transversely ridged or tuberculate. Clavicles are wanting. The testes are abdominal, and there are two mammary glands which are pectoral in position. The placenta is deciduate and zonary.*

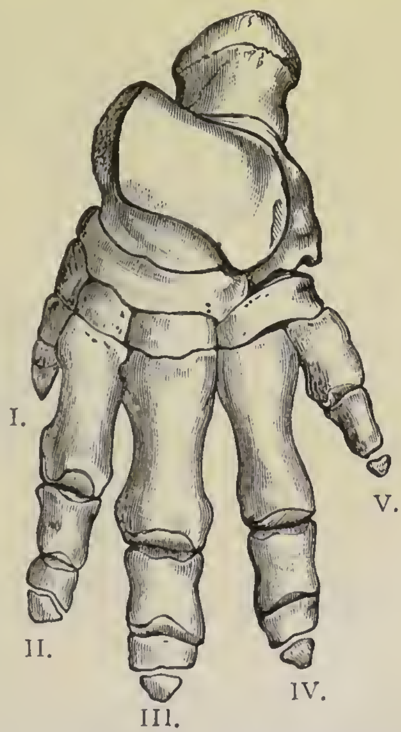


Fig. 506.—Hind-foot of the Indian Elephant (*Elephas indicus*). (After Cuvier.)

The Proboscideans are all terrestrial in their habits, and though some of the extinct Elephants were of no great size, they are all massively constructed animals, with the limbs very stout, and the femur nearly vertical. The fibula is complete and distinct from the tibia, and the femur is not furnished with a third trochanter. There are five digits in both the fore and hind feet (fig. 506), but all of these are not, as a rule, fur-

nished with hoofs. The hoofs are placed in front of a great palmar and plantar pad of horny skin, upon which the weight of the body is principally supported.

The skull in the Elephants is high and conical, with the cranial sutures more or less completely obliterated in the adult. The actual brain-case is of comparatively very small size, the extent of surface necessary for the attachment of muscles being secured by the development of great air-sinuses between the inner and outer tables of the skull (fig. 507). Similar air-cells are also de-

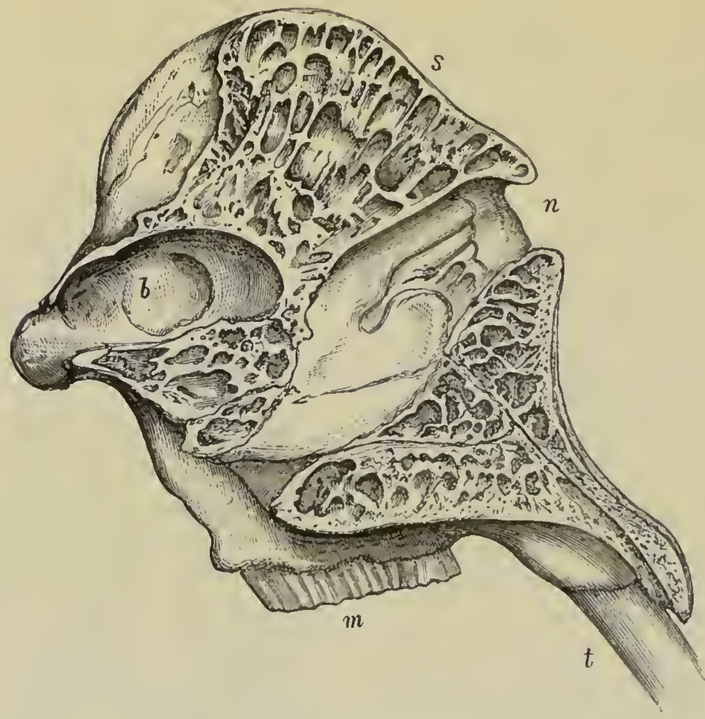


Fig. 507.—Section of the skull of the Indian Elephant (after Boyd-Dawkins and Oakley): *s* Air-sinuses; *n* Anterior nares; *b* Brain-case; *m* Molar; *t* Base of the tusk.

veloped in the nasals, præmaxillæ, maxillæ, and palatine bones. The nasal bones are very short and broad, the nasal passages are nearly vertical, and the anterior nares (fig. 507, *n*) are wide and are placed high up on the front of the head. The nose itself is prolonged into a great trunk-like "proboscis" (fig. 505), which is composed of an enormous number of interlacing muscular fasciculi, and terminates in a finger-like prehensile lobe, below which are placed the apertures of the nostrils. The proboscis is highly sensitive, and is movable in every direction. It is the sole organ of prehension possessed

by the animal, and is employed in conveying both food and water to the mouth.

The dentition of the Proboscideans consists of incisors and molars, canines being wanting in both jaws. In the Elephants the lower jaw is destitute of incisor teeth (fig. 508), and there are only two upper incisors, which become greatly developed and constitute the "tusks." The tusks are the only teeth in the jaws which have deciduous predecessors; but the milk-tusks are early shed, and never attain any great size. The permanent tusks are composed of dentine and cement, some extinct forms having an anterior strip of enamel as well; and they grow from permanent pulps, and often attain an enormous size, especially in old males. The molar teeth are of very large size (fig. 508), and are composed of transverse plates

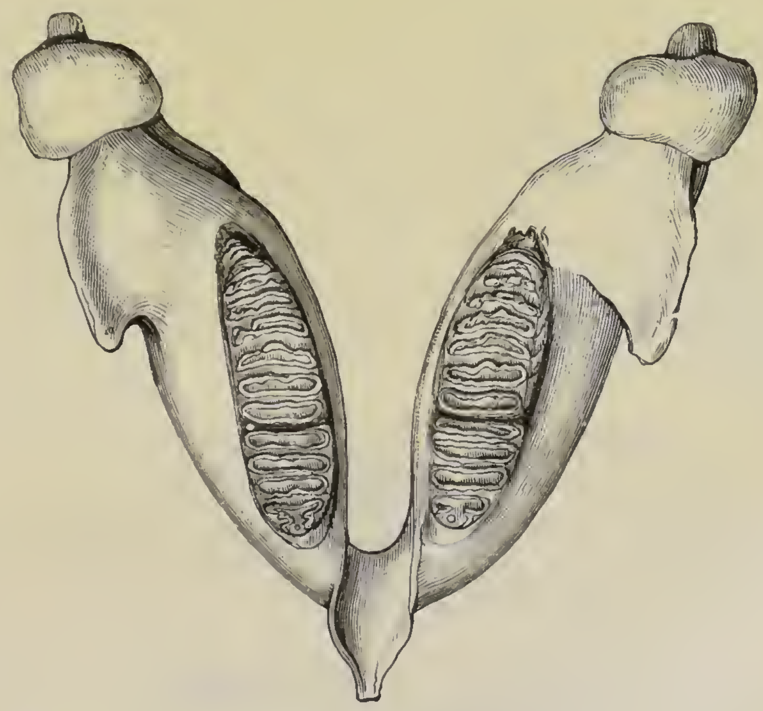


Fig. 508.—Lower jaw of the Indian Elephant (*Elephas indicus*), viewed from above, showing the molar teeth. Greatly reduced in size.

of enamel, which surround tracts of dentine, and are bound together by cement. As the tooth wears down by use, the enamel-plates come to project above the general surface, enclosing islands of dentine, the form of which varies in a characteristic manner in different species of Elephants. There

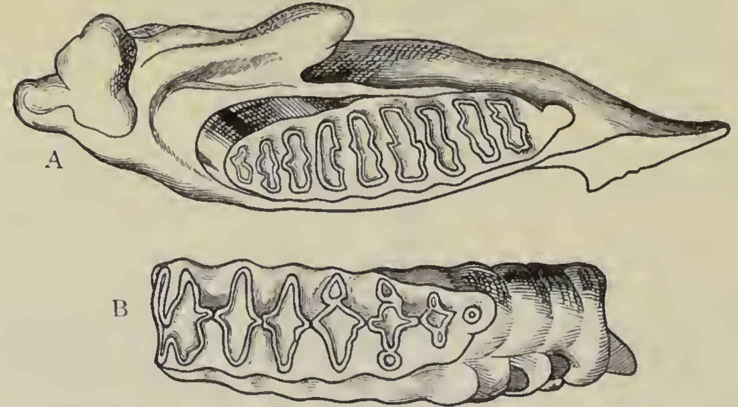
are six molars on each side of each jaw, the dental formula being thus—

$$i\,\frac{1-1}{0-0};\ c\,\frac{0-0}{0-0};\ m\,\frac{6-6}{6-6}=26.$$

Though the number of molars on each side of each jaw is really six, owing to their large size, and the manner in which they succeed each other in the jaw, there is never more than one (or parts of two) in use in each jaw at one time (fig. 508). The molars do not, in fact, succeed one another vertically; but they come into place successively from behind forwards. Thus the whole series of molars gradually moves forwards in the jaw, and the place of each tooth, as it slowly advances, is taken by the tooth next behind it in the series, all but the penultimate molar being lost when the last cuts the gum.

The only existing Proboscideans are the Elephants, of which there are only two living species, the African and the Indian Elephant, both confined to the tropical regions of the Old World, in the forests of which they live in herds. They are strictly phytophagous, living upon grass or the foliage of shrubs and trees, which they strip off by means of the prehensile trunk. As the tusks prevent the animal from drinking in the ordinary manner, the water is sucked up by the trunk, which is then inserted into the mouth, into which it empties its contents. The Elephants are uniparous, and the period of gestation is rather more than twenty months.

A



B

Fig. 509.—A, Left ramus of lower jaw of *Elephas indicus*, viewed from above (after Cuvier). B, Grinding-surface of molar tooth of *Elephas africanus* (after Giebel).

The Indian Elephant (*Euelephas*, or *Elephas*, *indicus*) is a native of India, Ceylon, Burmah, Siam, Cochin-China, the Malay Peninsula, and Sumatra. The Ceylon variety has sometimes been regarded as a distinct species. The Indian Elephant is distinguished by its concave forehead,

the comparatively small size of the ears, the possession of five hoofs on the manus and four hoofs on the pes, and the fact that the enamel-folds of the molars (fig. 509, A) are narrow and parallel. The general colour of the skin is pale brown, the so-called "White Elephants" being merely albinos. The tusks of the males are well developed, and grow to a length of six or seven feet, and a weight of sixty or seventy pounds, or more.

The African Elephant (*Loxodon*, or *Elephas, africanus*) inhabits Africa, south of the Sahara, and formerly extended its range as far as Cape Colony. It is distinguished by its strongly convex forehead, its great flapping ears, the possession of four hoofs on the manus and three hoofs on the pes, and the fact that the enamel-folds of the molar teeth (fig. 509, B) are lozenge-shaped. The African Elephant is not now domesticated, but is largely hunted for the sake of the tusks, these being developed in both sexes, but being smaller in the females than in the males.

The true Elephants are characterised by the flat, transversely-ridged crowns of the molar teeth. In the extinct genus *Mastodon* (fig. 510) the general characters resemble those of the

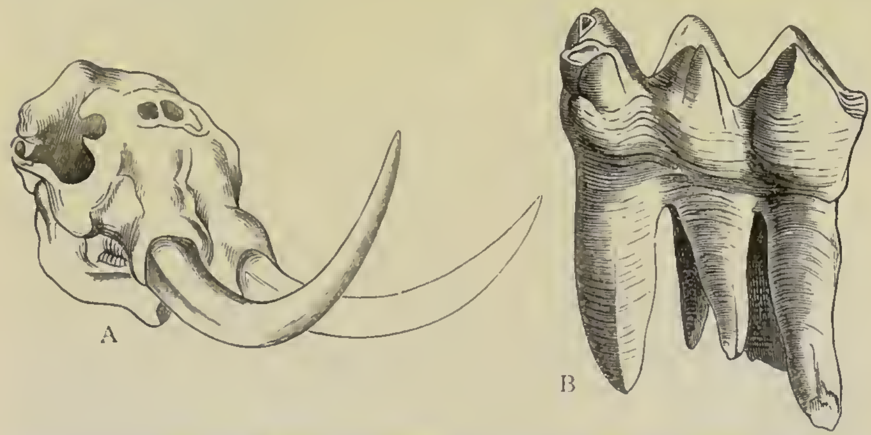


Fig. 510.—A, Skull of *Mastodon giganteum*; B, Side view of the second true molar of *Mastodon giganteum*. (After Owen.)

Elephants, but the crowns of the molar teeth present nipple-shaped tubercles arranged in pairs. The two upper incisors of the Mastodons were developed into long tusks, and lower incisors are usually wanting, as in recent Elephants; but in some cases two lower incisors were present in addition.

In the genus *Deinotherium*, which is usually referred to the order *Proboscidea*, there were no upper incisors, but the lower jaw is bent downwards towards its symphysis (fig. 511), and it carries two long tusk-like incisors. Canines were wanting in both jaws, and there were two præmolars and three molars on each side of each jaw. The grinders are crossed by strong transverse ridges (fig. 512), which give them a distinctly Tapiroid character. The species of *Deinotherium* attained gigantic dimensions, the general structure of the skeleton resembling that of the Elephants.

As regards the *distribution in time* of the Proboscideans, the genus *Deinotherium* is characteristic of the Middle Tertiary or Miocene period. The Mastodons begin in the Miocene

Fig. 511.—Skull of *Deinotherium giganteum.* Miocene Tertiary.

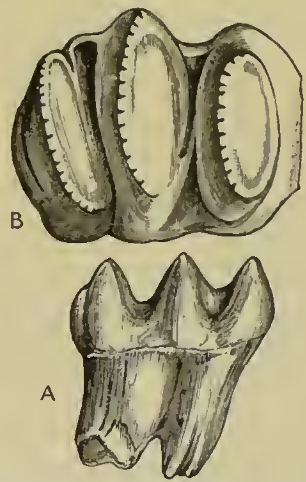


Fig. 512.—A, Side-view of the third molar of *Deinotherium giganteum;* B, Grinding surface of the same. Miocene Tertiary. (After Kaup.)

period, but they are also found in the Pliocene deposits, and survived into the Quaternary period. True Elephants appear for the first time in the Siwalik deposits of India, and Europe possessed well-known types of Elephants in Pliocene times (*E. meridionalis* and *E. priscus*). The best known, as well as the most modern, of the extinct Elephants is the Mammoth (*Elephas primigenius*), which formerly ranged over the whole of Northern Asia and Europe, and unquestionably survived into the human period. By the discovery of the bodies of Mammoths embedded in the frozen soil of Siberia, we know that this remarkable Elephant was furnished with a covering of long woolly hair.

CHAPTER LXXI.

CARNIVORA.

Order XII. Carnivora.—The order of the *Carnivora*—the *Feræ* of many writers—comprises the Beasts of Prey, which are characterised as *hairy Mammals, in which the toes*

are furnished with claws (much reduced in Seals), and the clavicles are rudimentary or absent. There are two sets of enamelled teeth, which are always of three kinds—incisors, canines, and molars—and which differ from another in shape and size. The incisors are never more than three on each side of each jaw, and the canines are always longer and more pointed than the incisors. Some of the præmolars and molars are usually furnished with cutting or trenchant edges, and the condyle of the lower jaw is transversely elongated. The orbits are not separated from the temporal fossæ, and the facial region of the skull is usually short. The intestine is comparatively short, and the stomach is simple. The mammary glands are abdominal, and the placenta is deciduate and zonary.

The Carnivora are adapted by their organisation for a raptorial life, and for a more or less exclusively carnivorous diet, though in exceptional cases the food is not of an animal nature at all. The adaptation here spoken of is especially conspicuous as regards the structure of the skull and the form of the teeth. The skull (fig. 513) generally possesses a more

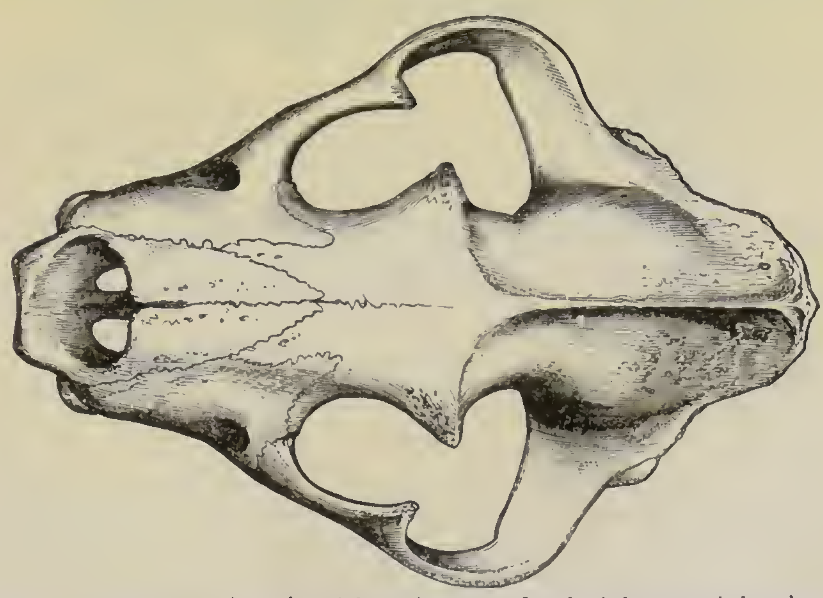


Fig. 513.—Skull of the Lion, viewed from above, one-fourth of the natural size, showing the sagittal crest, the wide zygomatic arches, and the incomplete orbits.

or less marked sagittal crest serving for the attachment of the powerful muscles of mastication. The orbits are continuous with the zygomatic fossæ; and the latter are very wide, so as to accommodate the powerful temporal and masseter muscles; the coronoid process of the mandible, to which the former of these muscles is attached, being unusually strong and high.

The condyle of the lower jaw is transversely elongated, so as to limit, or entirely prevent, movement of the jaw in any direction except a vertical one. The "tentorium," or fold of the dura mater separating the cerebellum from the cerebrum, is ossified.

The teeth are simple, their crowns covered with enamel, and all three kinds of teeth are present. Except in some Seals, there are always three incisors on each side of each jaw. The canines are always long and pointed. The crowns of the præmolar teeth and of the first lower molar are typically sharp-edged and trenchant, but they graduate from a cutting to a tuberculate form according as the diet is strictly of an animal nature, or becomes more or less miscellaneous.

In the typical and most highly specialised Carnivores (such as the *Felidæ*), the last præmolar in the upper jaw, and the first molar in the lower jaw (fig. 514, pm^3 and m) are specially

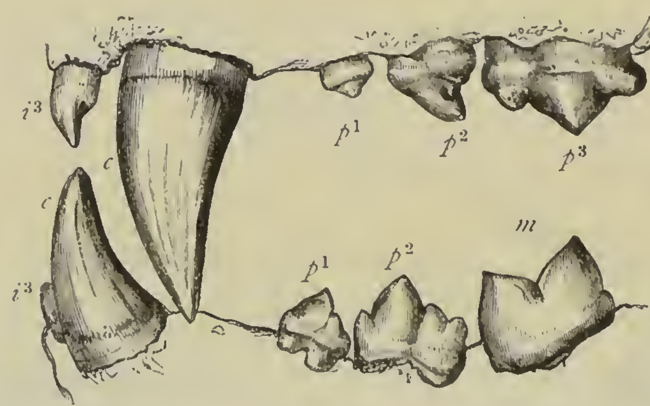


Fig. 514.—Permanent dentition of the Lion (*Felis leo*). In the upper jaw the letter p^3 indicates the upper carnassial, while in the lower jaw the letter m indicates the lower carnassial.

developed, and are known as the "carnassial" teeth, having a sharp cutting-edge; whereas in other cases the corresponding teeth are blunt and "tuberculated." Even in their most trenchant condition, the carnassial tooth commonly has a more or less developed tuberculated process, or "heel," on the inside of its cutting-edge. In various Carnivores a number, or all, of the præmolars and molars may be "tuberculate," their crowns being adapted for bruising rather than cutting. As a general rule, the shorter the jaw, and the fewer the præmolars and molars, the more carnivorous is the animal.

Clavicles are wanting, or are rudimentary, in all the *Carnivora*. The radius and ulna and tibia and fibula are complete, and

there are usually five digits to the feet. The digits are terminated by claws, the length and sharpness of which are generally in proportion to the degree in which the animal is strictly carnivorous. In the aquatic Carnivores (*Pinnipedia*), however, the claws are small or rudimentary. The structure of the feet varies in different groups of *Carnivora*. In the aquatic Carnivores (Seals and Walruses), the limbs are short, and the toes are united by the skin, thus converting the feet into swimming-paddles (fig. 515, B). In the Bears and various other forms of the order, the animal is "plantigrade," the foot

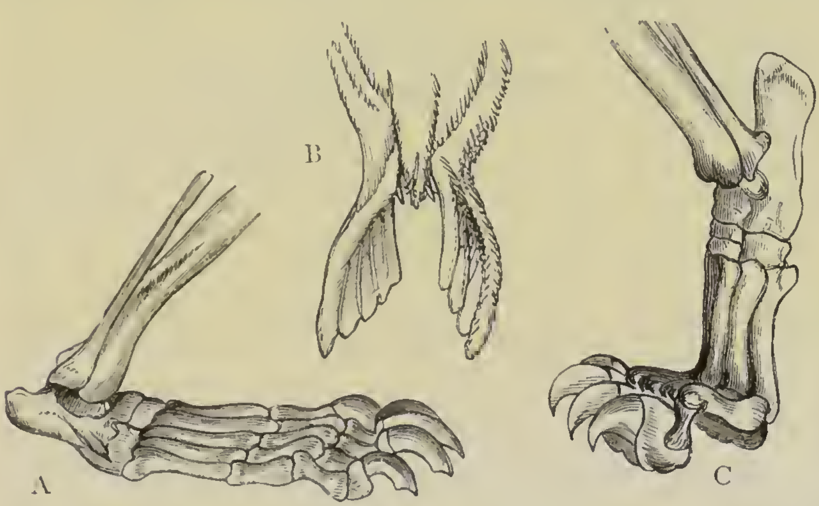


Fig. 515.—Feet of *Carnivora* (after Owen). A, *Plantigrada*, Foot of Bear; B, *Pinnigrada*, Hind-feet of Seal; C, *Digitigrada*, Foot of Lion.

being so constructed that the sole is wholly or in great part applied to the ground (fig. 515, A). On the other hand, in the Cats, Dogs, and Hyænas, the animal is "digitigrade," walking on the phalanges of the toes, the metacarpal and metatarsal bones being nearly vertical and not touching the ground at all (fig. 515, C).

The organs of hearing, smell, and vision are very highly developed in the *Carnivora*. The sense of taste is less developed, the papillæ of the tongue being often horny, enabling this organ to act mechanically, as a rasp, in licking the flesh off bones. Lastly, the skin in the *Carnivora* is very loosely attached to the subcutaneous structures.

As regards their *distribution in space*, the *Carnivora* are found more or less abundantly in all the great zoological provinces, with the exception of the Australian. Australia itself possesses the Dingo, but it is questionable if this is truly indigenous; while New Zealand and the various islands in-

cluded in the Australian province seem to be wholly without native Carnivores.

As regards their *distribution in time*, the earliest types of the order make their appearance in the later Eocene deposits (*Galecynus*); and the leading modern groups of the *Carnivora* are represented in the Miocene Tertiary. The Ursidæ (Bears) appear in the Miocene (*Hyænarctos*), and various forms of *Ursus* itself are found in the Pliocene and Post-pliocene. The Civet-cats (*Viverridæ*) appear in the Upper Eocene (*Tylodon* and *Palæonyctis*); and the Miocene genus *Ictitherium* seems to connect the Civet-cats with the Hyænas. The great group of the *Canidæ* is known by various fossil forms, of which the *Amphicyon* of the Miocene Tertiary is one of the most interesting, its plantigrade foot bringing it into relation with the Bears. True Hyænas appear to have existed in the late Miocene (Pliocene) deposits. Lastly, the *Felidæ* (Cats) commence in the Upper Eocene, and are represented in the Miocene deposits by numerous forms. One of the most remarkable of the extinct *Felidæ* is the genus *Machairodus*, comprising the so-called "Sabre-toothed Tigers," in which the huge canines are compressed and sabre-shaped, and have finely serrated margins.

As regards the *classification* of the *Carnivora*, the order has often been divided in accordance with the structure of the feet into the three groups of the *Pinnipedia*, *Plantigrada*, and *Digitigrada*. A more natural arrangement, however, is to divide the order into the two primary sections, or sub-orders, of the *Pinnipedia* and *Fissipedia*, the former comprising the aquatic Seals and Walruses, while all the ordinary terrestrial Carnivores are included in the latter.

Pinnipedia.

Sub-order I. Pinnipedia. — This division comprises the Seals and Walruses, characterised by their adaptation to an aquatic mode of life. The body (fig. 516) is elongated, covered with a short dense fur, more or less largely interspersed in many cases with long harsh hairs, and terminated posteriorly by a short conical tail. All the four limbs are present, but are very short, and have the digits united by the skin so as to form swimming-paddles. The feet have five toes each, but the nails are small or almost wanting. The hind-feet of the typical Seals are placed far back, nearly in a line with the axis of the body (fig. 516), and are more or less closely bound down by the integuments to the tail. The

hind-limbs are thus admirably adapted for swimming, but little suited for terrestrial progression. The ordinary Seals, in fact, can only drag themselves laboriously along, when on

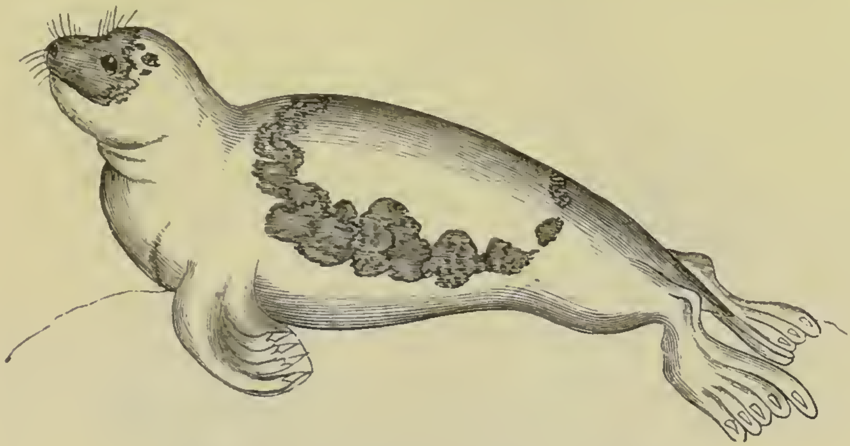


Fig. 516.—The Greenland Seal (*Phoca grœnlandica*).

the land, chiefly by the contractions of the abdominal muscles. On the other hand, the Eared Seals (*Otariadæ*) and the Walruses have the hind-limbs less closely pinned down, and not directed backwards in the axis of the body, and thus can move upon the land with considerable freedom.

The skull of the Pinnipedes is more or less smooth and free from muscular ridges, the brain-case and orbits being of large size. The hinder part of the skull is broad and rounded, but the interorbital region is much contracted. The dentition varies, but teeth of three kinds are always present, in the young animal at any rate. The canines are always long and pointed, and the præmolars and molars (except in the Walruses) have serrated crowns. The lower incisors may be reduced to four or to two in number, or may even be wanting (Walrus); and the upper incisors may fall below the normal six. The dental formula of the common Seal (fig. 517) is—

$$i\,\frac{3-3}{2-2};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{4-4}{4-4};\quad m\,\frac{1-1}{1-1}=34.$$

The Seals have a thick layer of fat below the skin. In the Eared Seals alone is the ear furnished with a small pinna, all the other members of the group having the ears only indicated by small external apertures, which can be closed when the animal is under water. The lungs are remarkably capacious, and submersion for proportionately long periods can be borne without injury. The intestine is much longer than

in the typical Carnivores, sometimes reaching fifteen times the length of the body, and the food consists of fishes, shell-fish, and other marine animals.

The section *Pinnipedia* includes the three families of the

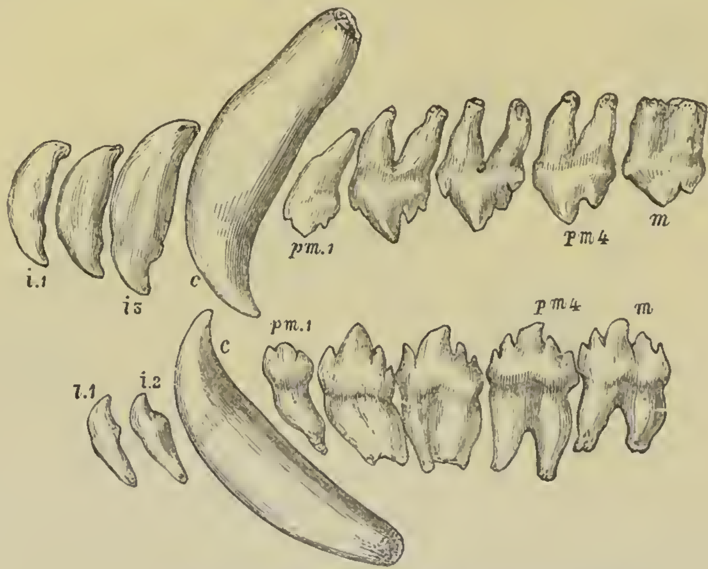


Fig. 517.—Dentition of the Common Seal (*Phoca vitulina*).

Earless Seals (*Phocidæ*), the Eared Seals (*Otariadæ*), and the Walruses (*Trichechidæ*).

The typical Seals (*Phocidæ*) are distinguished from the Walruses by the presence of incisor teeth in both jaws, and by canines of moderate size; while the absence of ears and the inability to use the hind-limbs on land separate them from the *Otariadæ*. They form a very numerous family, of which species are found in almost every sea out of the limits of the tropics. They abound, however, especially in the seas of the Arctic and Antarctic regions. They live for the most part upon fish, and when awake, spend the greater part of their time in the water, only coming on land to bask and sleep in the sun, and to bring forth their young. They appear to be universally polygamous. The body is covered with a short fur, interspersed with long bristly hairs; and the lips are furnished with long whiskers, which act as organs of touch. The Seals are very largely captured for the sake of their blubber.

The only common British Seal is the *Phoca vitulina*, which occurs not uncommonly on the northern shores of Scotland, and ranges over almost the whole of the shores washed by the North Atlantic and the seas of Greenland. It is yellowish-grey in colour, and measures from three to five feet in length. Other Seals attain a much greater length—the Great Seal measuring from eight to ten feet, and the Elephant Seal (*Macrorhinus*), of the South Pacific, reaching a length of twenty feet.

The Eared Seals or Sea-lions (*Otariadæ*) differ from the typical Seals in the possession of small conical ears, and in the much greater freedom of the limbs, enabling the animal to walk with comparative ease on land. The Eared Seals are principally found on the shores of the continents and

islands washed by the Pacific; but they are also found in the extreme southern part of the Atlantic as far northwards as the mouth of the Rio Plata. Among the various interesting forms included in this family, the well-known Alaskan "Fur Seal" (*Callorhinus ursinus*) may be mentioned, but space will not permit an account of its habits and of the remarkable phenomena connected with its reproduction.

The third family of the *Pinnipedia* is that of the *Trichechidæ*, comprising only the Walruses (*Trichechus*). Only two species of Walrus are known—viz., the Atlantic Walrus or Morse (*Trichechus*, or *Odobænus*, *rosmarus*), and the Pacific Walrus (*T. obesus*). The chief peculiarities of this family,

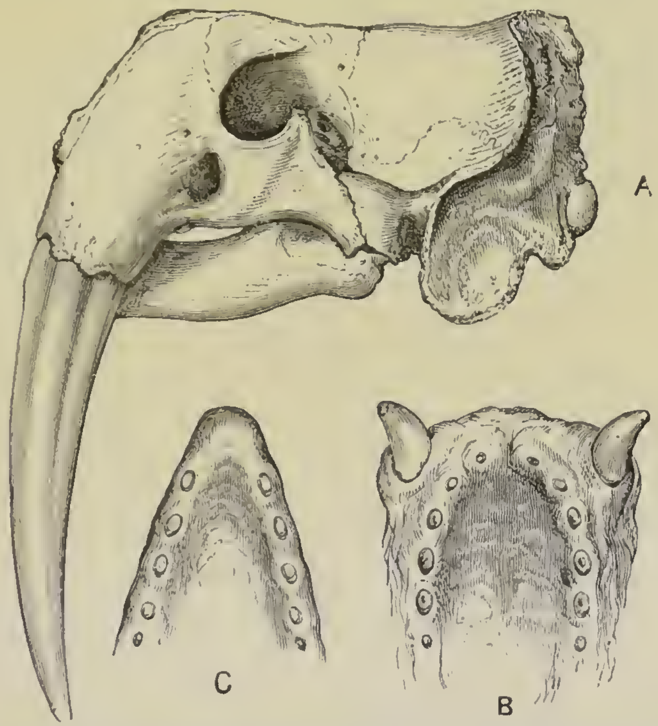


Fig. 518.—Skull and dentition of the Atlantic Walrus. (After de Blainville and Murie). A, Skull of adult, showing the tusk-like upper canines; B, Palate and dentition of the young animal; C, Lower jaw and dentition of the young animal.

as compared with the preceding groups, are found in the dentition, which, owing to the early disappearance of certain of the teeth and to the common occurrence of individual variations, has been differently described by different observers. According to Mr Allen, whose views are essentially in accord with those of Professor Flower, the dental formula for the milk-dentition of the Walrus is—

$$i\,\frac{3-3}{3-3};\quad c\,\frac{1-1}{1-1};\quad m\,\frac{4-4}{4-4}=32.$$

The dental formula for the permanent dentition, on the other hand, is—

$$i\,\frac{1-1}{0-0};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{4-4}{4-4};\quad m\,\frac{1-1}{1-1}=26.$$

The special peculiarities of the permanent dentition of the Walruses are—

(1) The whole of the lower incisors disappear in the adult, as do all the upper incisors except the outermost incisor on each side. (2) The upper canines are enormously developed, growing from permanent pulps to a length of a foot or a foot and a half, and being directed downwards so as to project far below the chin (fig. 518, A). (3) The lower canines are small, and are like the præmolars in form. (4) The last upper præmolar and the upper molar usually disappear in the adult, as also does the lower molar on each side.

Except as regards the dentition and the absence of external ears, the Walruses agree in most respects with the Eared Seals, especially in the comparative freedom of the limbs. They are large and heavy animals, attaining a length of ten or fifteen feet or upwards. The body is covered with short hair, and the face bears many long stiff bristles. The great tusk-like upper canines are employed as weapons of offence and defence, and for digging up burrowing shell-fish out of the sand or mud of the sea-bottom; and they are also used to assist the unwieldy animal in getting out of the water upon the ice. The Atlantic Walrus is abundant in the Arctic seas, living in herds; the Pacific Walrus being found in corresponding latitudes on the western side of the American continent.

FISSIPEDIA.

SUB-ORDER II. FISSIPEDIA.—This section of the *Carnivora* includes terrestrial forms, in which the foot is adapted for walking on land (rarely webbed for swimming also), and the toes have well-developed claws. The Fissipede Carnivores admit of a natural division into the three groups of the *Arctoidea* (Bears and their allies), the *Cynoidea* (Dogs, Wolves, &c.), and the *Æluroidea* (Cats, Hyænas, Civets).

SECTION 1. ARCTOIDEA.—The forms included in this group have commonly been spoken of as the "Plantigrade Carnivora" (*Plantigrada*), as they apply the whole or the greater part of the soles of the feet to the ground in progression (fig. 519). Except in the Polar Bear, the soles of the feet are naked; and in all cases there are five clawed digits to each foot. The tympanic bones are dilated into "tympanic bullæ," but these are of comparatively small size, and are not divided into two by an internal septum; while the external auditory meatus is of considerable length. The intestine, lastly, is without a cæcum.

The section of the *Arctoidea* includes the four families of the *Ursidæ* (Bears), the *Procyonidæ* (Racoons, Coatis, &c.), the *Æluridæ* (Panda), and the *Mustelidæ* (Weasels, Badgers, Otters, &c.).

The typical family of the *Arctoidea* is that of the *Ursidæ*, including only the Bears. The Bears are much less purely carnivorous than the majority of the Beasts of Prey, and, in accordance with their omnivorous habits, the teeth do not

exhibit the typical carnivorous characters. The incisors and canines have the ordinary carnivorous form, but the "carnas-

Fig. 519.—The Brown Coati (*Nasua fusca*), showing the plantigrade form of the feet.

sial" teeth have tuberculate crowns, instead of a sharp cutting-edge. The dental formula in *Ursus* (fig. 520) is—

$$i\,\frac{3-3}{3-3};\ \ c\,\frac{1-1}{1-1};\ \ pm\,\frac{4-4}{4-4};\ \ m\,\frac{2-2}{3-3}=42.$$

The dental formula of the Bears is thus the same as that of the Dogs; but the second and third præmolars are small and usually deciduous, while the first præmolar is also often caducous. The last præmolar and all the molars have tuberculate crowns, and the carnassials are not of specially large size, these characters being equally present in the flesh-eating Polar Bear and the strictly vegetarian Sun-bear.

The skull of the Bears exhibits fairly well-developed muscular ridges, and the muzzle is elongated. The claws are formed for digging, being large, strong, and curved, but not retractile. The tongue is smooth; the ears small, erect, and rounded; the tail short; the nose forms a movable truncated snout; and the pupil is circular.

As shown by their smooth tongues and tuberculate molars, the Bears are not peculiarly or strictly carnivorous. They eat flesh when they can obtain it, but in most cases a great part of their food is of a vegetable nature.

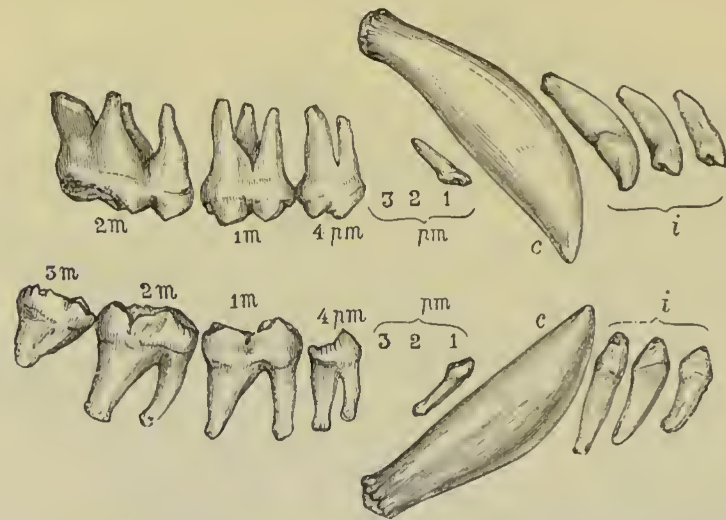


Fig. 520.—Dentition of the Polar Bear (*Thalassarctos maritimus*). The deciduous second and third præmolars have disappeared.

The Bears are very generally distributed over the globe, Australia and Africa alone having no representative of the family. The common Brown Bear (*Ursus arctos*) was at one time an inhabitant of Britain, and also existed over the whole of Europe. At the present day the Brown Bear is only found in the great forests of the north of Europe and Asia, and in the Arctic portions of North America. It feeds on roots, fruits, honey, insects, and, when it can obtain them, upon other Mammals. It attains a great age, and hibernates during the winter months. Very nearly allied to the Brown Bear is the Black Bear of America (*Ursus americanus*). Both are of some commercial value, being hunted for the sake of their skins, fat, and tongues. A much larger American species is the Grizzly Bear (*Ursus ferox*), found in many parts of the North American continent. It is about twice as large as the Black Bear, but, though largely carnivorous, it is said to subsist to some extent upon vegetable food, such as acorns. The most remarkable, however, of the Bears is the great White Bear (*Thalassarctos maritimus*), which is exclusively a native of the Arctic regions. It is a very large and powerful animal, the fur of which is cream-coloured. The paws are very long, and the soles of the feet are covered with coarse hair, giving the animal a firm foothold upon the ice. The Polar Bear differs from the other *Ursidæ* in being exclusively carnivorous, since vegetable food would be generally unattainable. It is as much at home in the water as on land, and lives chiefly upon seals and fish, and the carcasses of Cetaceans.

Amongst the other Bears may be mentioned the Sun-bears (*Helarctos*) of the Malayan Archipelago, the Honey-bears (*Prochilus* or *Melursus*) of India, and the Spectacled Bear (*Helarctos*, or *Tremarctos*, *ornatus*) of the Peruvian and Chilian Andes, the sole representative of the *Ursidæ* in South America.

The family *Procyonidæ* includes a number of small American Carnivores, which are nearly allied to the Bears, but which differ from the latter in the greater development of the "tympanic bullæ," and in the fact that there is a molar less on each side of the lower jaw. The type of the group is the genus *Procyon* (the Racoons), in which the dental formula is—

$$i\,\frac{3-3}{3-3};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{4-4}{4-4};\quad m\,\frac{2-2}{2-2}=40.$$

The Racoons (*Procyon*, fig. 521) are natives of tropical and northern America, and have a decided external resemblance to the Bears. They have tolerably long tails, however, and sharp muzzles. The commonest species is the *Procyon lotor* of North America, which derives its specific

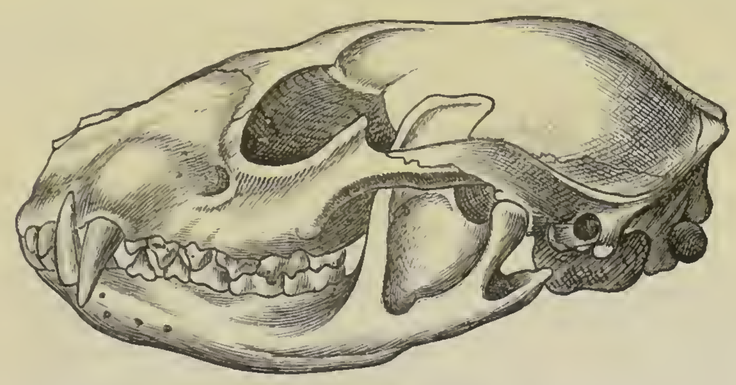


Fig. 521.—Skull of Racoon (*Procyon lotor*). (After Giebel.)

name from its habit of soaking its food in water before eating it. The Coatis (*Nasua*, fig. 519) are nearly allied to the Racoons, and are exclusively confined to the Neotropical province, ranging from Mexico to Paraguay. The Kinkajou (*Cercoleptes*) is likewise Neotropical in its range, and is arboreal in its habits, its tail being prehensile. In general appearance it somewhat resembles the Lemurs. Lastly, forming a transition between the *Procyonidæ* and the Civets (*Viverridæ*), is the curious "Cacomixle" (*Bassaris astuta*), which is likewise arboreal in its habits, and is a native of California, Texas, and parts of Mexico.

The small family of the *Æluridæ* comprises only the well-known "Wah" or "Panda" (*Ælurus fulgens*) of India and Thibet, and the *Æluropus* of the latter country. The former is a cat-like animal, chestnut-brown above and black inferiorly, with a white face and ears; and the latter is almost completely white in colour. Like the Kinkajous, but unlike the Coatis and Racoons, the *Ælurus* has semi-retractile claws.

The remaining members of the Arctoid *Carnivora* are now very generally grouped together to form a single family, to which the name of *Mustelidæ* is applied, and which comprises

not only the Weasels and Polecats and their allies, but also the Badgers and Otters. All these forms agree in the fact that there is only a single upper molar, and that there are usually two (never more) lower molars on each side. With hardly an exception, the last upper præmolar (the upper carnassial) has a cutting-edge. All the members of this family, further, possess anal glands, which produce a malodorous secretion.

The Badgers have often been regarded as forming a separate family (*Melidæ*). They differ from the more typical *Mustelidæ* in their completely plantigrade progression. The dental formula of the Badger is as follows (Baird)—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{3-3\ (4-4)};\ m\,\frac{1-1}{2-2} = 34\ (36).$$

The first præmolar in the lower jaw is very minute, and is soon lost; the upper carnassial has a well-marked internal tubercle; and the upper molar is of comparatively large size, nearly equalling the carnassial in its dimensions.

The common Badger (*Meles taxus*), which may be regarded as the type of this group, occurs in Britain, and is one of the most inoffensive of animals. It is nocturnal in its habits, and is a very miscellaneous feeder, not refusing anything edible which may come in its way, though living mainly on roots and fruits. The Badger burrows with great ease, and can bite very severely. The European Badger is represented in the United States and Canada by the "Siffleur" (*Taxidea labradorica*), and in the hilly parts of India by the Indian Badger (*Meles* or *Arctonyx collaris*).

Resembling the Badgers in their strictly plantigrade progression, but differing in other characters, are the Skunks (*Mephitis*). These are all American, and are celebrated for the horrible and unendurable odour of the anal secretion. The best-known species is the common Skunk (*M. mephitica*), the bite of which occasionally produces a form of rabies.

The Ratels or Honey-badgers (*Mellivora*) differ from the true Badgers, and, indeed, from all the *Mustelidæ*, in the fact that they have only the first or carnassial molar on each side of the lower jaw, the second molar being lost. They live largely upon Bees and other insects, and are natives of the Ethiopian province and of India.

The Otters (*Lutra*) are distinguished from the other *Mustelidæ* by the fact that the toes are webbed, thus adapting the animal for swimming. The body is long, the legs short, and the tail long, stout, and horizontally flattened. The præmolars and molars are furnished with sharp-pointed cusps (figs. 522, 523), and the last upper præmolar (carnassial tooth) has a cutting-edge and internal "heel." The common Otter (*Lutra vulgaris*) is a not uncommon British animal, living upon fish, and frequenting the banks of streams. A closely allied form is the American Otter (*Lutra canadensis*).

The Sea-otters (*Enhydris*) differ from the preceding in

many points, and especially in the disproportionate size of the hind feet, and in their dentition. There are only two lower incisors on each side, instead of three, and the upper carnassial is furnished with blunt tubercles, as are all the other back-

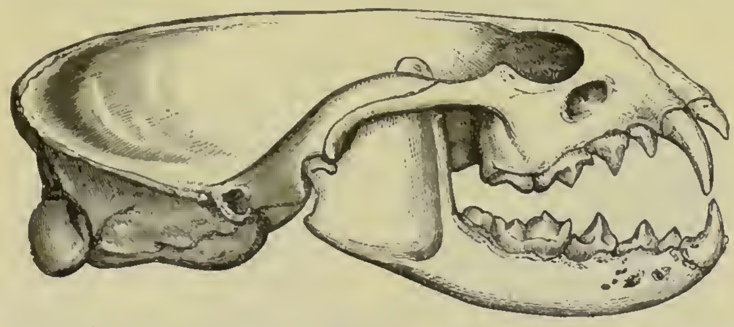


Fig. 522.—Skull of the Common Otter (*Lutra vulgaris*), viewed from one side. (After Coues.)

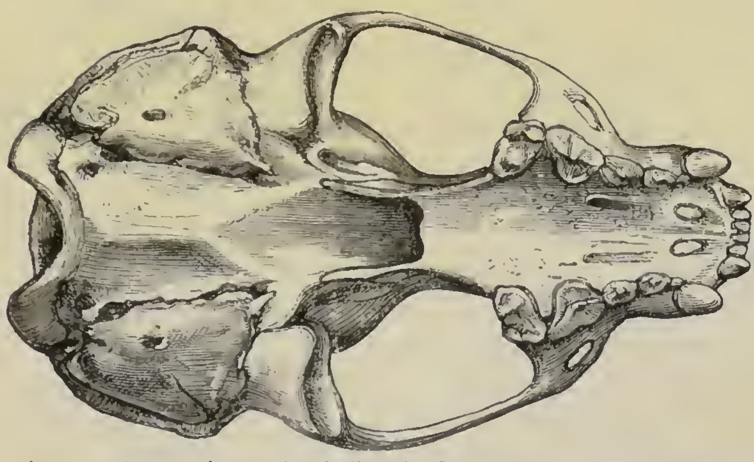


Fig. 523.—Under view of the skull of the Common Otter. (After Coues.)

teeth. The only known species of *Enhydris* is found on both sides of the North Pacific, and is greatly prized for its fur.

The typical group of the *Mustelidæ* is that of the Weasels and Pole-cats and their allies, which are mostly small Carnivores, with short legs, elongated worm-like bodies, and a peculiar gliding mode of progression (hence the name of "Vermiform" Carnivora sometimes applied to the group). The progression is semi-plantigrade, only part of the soles of the feet being applied to the ground. Anal glands are always present, and their secretion is mostly of a highly offensive character. The dental formula of *Mustela* proper is—

$$i\,\frac{3-3}{3-3};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{4-4}{4-4};\quad m\,\frac{1-1}{2-2}=38.$$

In the nearly-allied genus *Putorius* (fig. 524) there is a præmolar less above and below.

Among the best known of the *Mustelidæ* are the common Weasel (*Putorius vulgaris*), the Polecat (*Putorius fœtidus*), and the Ferret (*Putorius furo*), the last being an albino variety (now permanent) of one

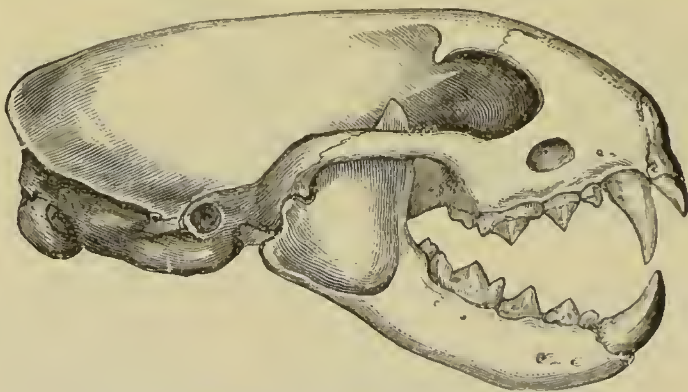


Fig. 524.—Skull of the Polecat (*Putorius fœtidus*).

of the Polecats. It is really an African form, but it has been long domesticated in Europe. Nearly-allied types are the Ermine or Stoat (*Putorius erminea*), and the Minks (*P. vison* and *P. lutreola*) of North America and Europe. Among the species of *Mustela* proper may be mentioned the Pine-marten (*M. martes*) and Stone-marten (*M. foina*) of Europe and Asia, the Pekan or "Fisher" (*M. Pennantii*) of North America, the true Sable (*M. zibellina*) of northern Asia, and the American Sable (*M. americana*). The *Mustelidæ* are of commercial importance as yielding beautiful and highly-valued furs, the skins of the Sable, Ermine, Black Mink, and Pekan being specially sought after.

The largest of the *Mustelidæ* is the Glutton or Wolverene (*Gulo luscus*), which is a native of the northern parts of Europe, Asia, and North America, and is celebrated for its strength and cunning. Allied to this are the Grisons (*Galictis*) of South America.

SECTION 2. CYNOIDEA. — This section of the Fissipede *Carnivora* comprises the Dogs, Wolves, Foxes, &c., characterised by their digitigrade progression, non-retractile claws, pointed muzzles, and smooth tongues. The tympanic bones are developed into large "tympanic bullæ" (fig. 525, *b.ty*), which are imperfectly subdivided by an incomplete bony septum; and there is a short external meatus auditorius, external to the membrana tympani. The intestine is furnished with a large cæcum. There are four præmolars and two molars on each side of the upper jaw, and four præmolars and three molars on each side of the lower jaw. This section includes only the single family of the *Canidæ*, comprising the Dogs, Wolves, Foxes, and some other less familiar forms.

The typical members of the *Canidæ* (Dogs, Wolves, and Foxes) have the fore-feet pentadactylous, and the hind-feet tetradactylous, and they all walk upon the tips of the toes and have non-retractile claws. In the characters of the skull and teeth they are intermediate between the Bears on the one hand and the Cats on the other hand. The facial region of

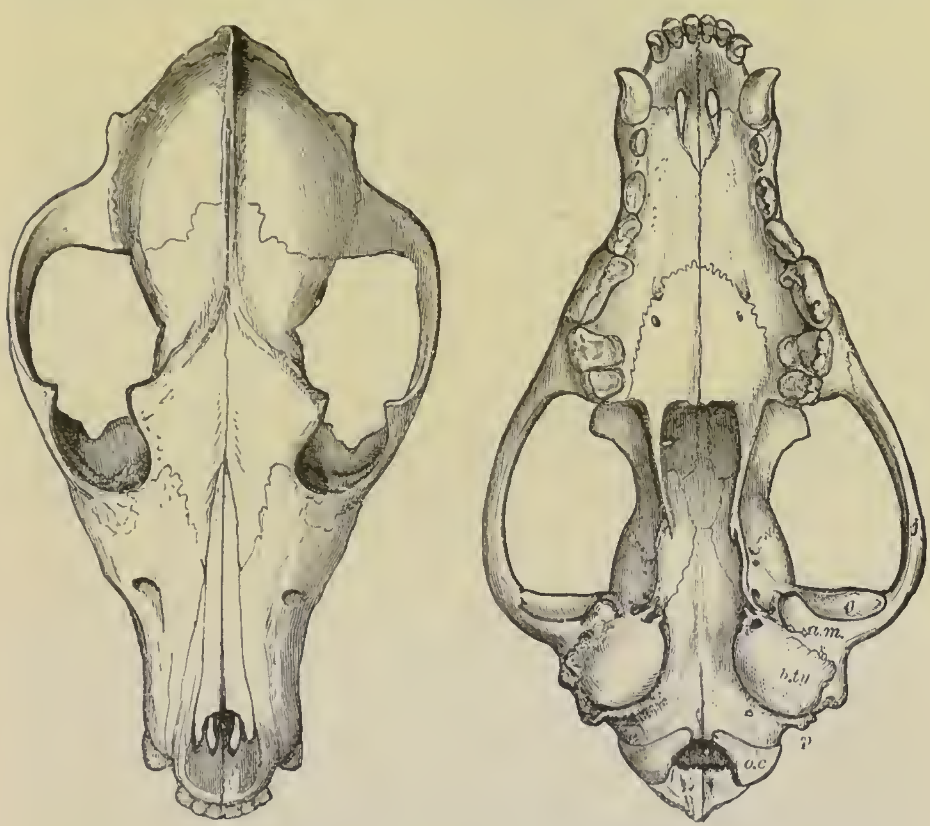


Fig 525.—Upper and under views of the skull of the Wolf (*Canis lupus*). *b.ty* Tympanic bulla.

the skull is elongated, to make room for the numerous teeth. The sagittal crest (except in some domestic breeds of the Dog) is well developed, and the zygomatic arches (fig. 525, *j*) are moderately, but not excessively, wide. The dental formula is—

$$i\ \frac{3-3}{3-3};\ c\ \frac{1-1}{1-1};\ pm\ \frac{4-4}{4-4};\ m\ \frac{2-2}{3-3} = 42.$$

The carnassial teeth (last upper præmolar and first lower molar) are of large size, and have cutting-edges. The two upper molars and the last two lower molars have tuberculate crowns (fig. 526). The first and second præmolars not un-

usually disappear in advanced life. As there are only *three* deciduous molars on each side of each jaw in the milk-dentition, the first præmolar of the adult may be regarded as a permanent tooth which has no predecessor.

Fig. 526.—Dentition of the Wolf (*Canis lupus*). p^4 Upper carnassial; m^1 Lower carnassial.

The domestic Dog (*Canis familiaris*) must have come under the dominion of man in times long anterior to written history. Few animals have undergone more numerous or striking variations, and some of the varieties are of great antiquity. In all probability, the dog has originated from more than one wild species of *Canidæ*. Some of the larger breeds of the Dog are closely allied to Wolves. Osteologically the Dog and Wolf are practically identical; while in both the period of gestation is the same (sixty to sixty-seven days), and the two interbreed and produce fertile offspring. The differences between such breeds of the Dog as the Eskimo Dog, or even the Sheep-dog, and the Wolf are very slight. Thus, Dogs have a round eye, erect or erectile ears, and a curled-up tail, and express their feelings by barking. On the other hand, Wolves have an oblique eye, drooping ears, and a half-scared, half-sinister expression, while they hang their tails, and howl instead of barking. Some of the smaller breeds of the Dog, again, have probably descended from the Jackals. Dogs readily become "feral," in which condition they often become more or less uniform in colour, and lose their habit of barking. Of the many so-called "Wild Dogs" of the present day, it is not probable that any are really wild species. It is possible that the "Dingo" of Australia is an exception to this statement; but the so-called "native Dog" of New Zealand has almost certainly been introduced by human agency into this region.

Of the Wolves, the common Wolf (*Canis lupus*) still abounds in some parts of Europe, and ranges over all Northern Asia, while there seems little reason for doubting that the common North American Wolf (*C. occidentalis*) is only a variety of it. Another variety is the Wolf of Palestine; and the Wolf of India and Wolf of Thibet are nearly related forms. A more completely distinct species is the "Coyote" or Prairie Wolf (*C. latrans*) of North America.

The Jackals are small *Canidæ* with a round pupil to the eye, and a slender pointed muzzle. The Jackals are gregarious, hunt in packs, and burrow in the ground. The common Jackal (*Canis aureus*) is widely distributed over Southern Asia and Africa, and allied species, or strongly marked varieties, are found in Africa. Taking the place of the Jackals in South America are the fox-like *Canis Azaræ* and *C. cancrivorus*.

The Foxes are distinguished from the other *Canidæ* by the fact that the pupil is vertical and slit-like; and they are hence often placed in the separate genus *Vulpes*. They have slender pointed muzzles and bushy tails. The common Fox (*Vulpes vulgaris*) is found over most of Europe, Asia, and North Africa, and is represented in North America by the varietal form known as the Red Fox (*V. fulvus*). Other well-known Foxes are the Silver Fox of North America (*V. virginianus*), and the "Fennec" (*Canis zerda*) of Africa.

One of the most aberrant members of the *Canidæ* is the curious *Lycaon pictus*, or "Hunting Dog," of South Africa, which agrees with the Dogs in its dentition and osteology, but resembles the Hyænas in the fact that all the feet are tetradactylous. Other aberrant members of the *Canidæ* are the long-eared *Megalotis Lalandii* of South Africa, and the Racoon-dog (*Nyctereutes procyonoides*) of Eastern Asia.

SECTION 3. ÆLUROIDEA.—This section of the Fissipede *Carnivora* comprises the Civet-cats, the Hyænas, the Aard-wolf, the *Cryptoprocta*, and the Cats, most of which walk on the tips of the toes. For this reason these forms have often been included with the *Canidæ* in a single division, under the name of *Digitigrada*. The claws are usually retractile, but are non-retractile in the Hyænas. The tympanic bones are expanded into large tympanic bullæ, and the external meatus auditorius is so short as to be flush with the surface of the bulla. Except in the Hyænas, the bulla is, further, divided internally into two nearly completely separate chambers by a bony septum. The outermost of the two chambers thus produced is the smallest, and is the true tympanic chamber. Only in the *Viverridæ* is there more than a single molar on each side of each jaw; the carnassials have cutting-edges; and the intestine has a short cæcum.

The Civet-cats (*Viverridæ*) are all of moderate size, with sharp muzzles and long tails, and mostly more or less striped, or banded, or spotted. Their progression is semiplantigrade, or sometimes almost plantigrade, and the claws are semi-retractile. The facial region of the skull is elongated, to make room for the lengthy series of teeth. The canines are not of

exceptionally large size, and most of the back teeth are rather cuspidate than trenchant. The two upper molars and the last lower molars are tuberculate. The tongue is roughened by horny papillæ, and the pupil is vertical and slit-like. The dental formula of *Viverra* is—

$$i\,\frac{3-3}{3-3};\; c\,\frac{1-1}{1-1};\; pm\,\frac{4-4}{4-4};\; m\,\frac{2-2}{2-2} = 40.$$

The Civet-cats are furnished with a pair of anal glands which produce an odorous, or malodorous substance. All the *Viverridæ* belong to the Old World.

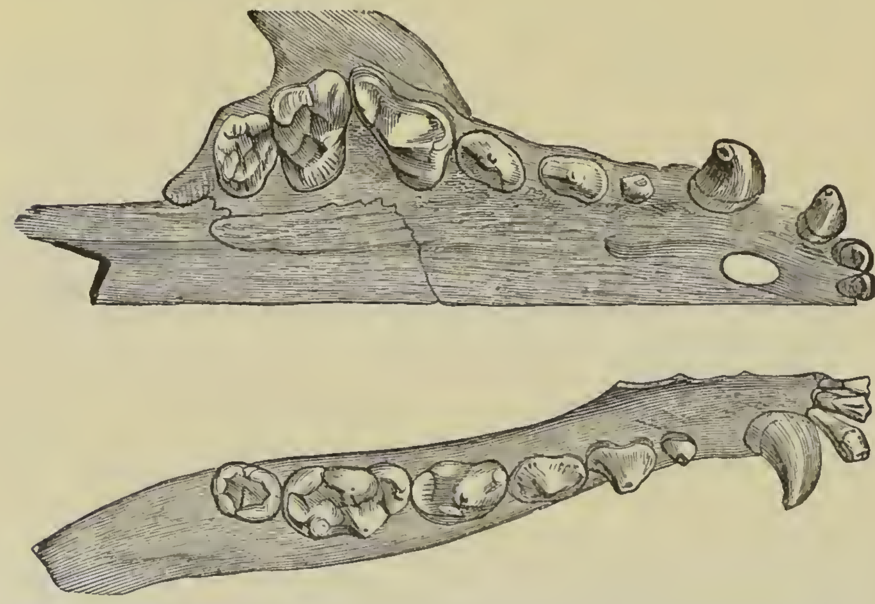


Fig. 527.—Dentition of the Civet-cat (*Viverra civetta*). The upper figure shows the upper jaw, the lower figure gives the lower teeth.

The true Civet-cat is the *Viverra civetta*, a native of Africa. It is a small nocturnal animal, which climbs trees with facility, and feeds chiefly upon small mammals, reptiles, and birds, but also upon roots and fruits. It furnishes the greater part of the "civet" of commerce, which was formerly in great repute both as a perfume and as a medicinal agent. It is a pomade-like substance, with a strong musky odour, and is secreted by a deep double pouch beneath the anus. Allied species inhabit the Oriental province. The Genette (*Viverra genetta*) is very closely related to the preceding, and is a native of Africa and Southern Europe, being not uncommonly domesticated and kept like a cat. The anal pouch in the Genette is much reduced in size, and has hardly any perceptible secretion. Another nearly-allied form is the Ichneumon (*Herpestes ichneumon*), one species of which is kept as a domestic animal in Egypt, and lives upon Snakes, Lizards, the eggs of the Crocodile, and small Mammals. Belonging also to the genus *Herpestes* is the little "Mungoos" (*H. griseus*) of India, celebrated for killing poisonous Snakes.

Among the numerous other forms which are referred to the *Viverridæ*

may be mentioned the *Paradoxurus* of the Indian province; the prehensile-tailed "Binturongs" (*Arctictis*) of India, Sumatra, and Java; the web-footed *Cynogale* of Borneo; the "Mangue" (*Crossarchus*) of Western Africa: and the "Suricate" (*Rhyzæna*) of South Africa.

The curious little *Cryptoprocta* of Madagascar, which is still imperfectly known, is usually regarded as the type of a special family (*Cryptoproctidæ*). The toes in *Cryptoprocta* are furnished with retractile claws, and the gait is semiplantigrade. The dental formula agrees numerically with that of the Hyænas—

$$i\,\frac{3-3}{3-3};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{4-4}{3-3};\quad m\,\frac{1-1}{1-1}=34.$$

Intermediate between the Civet-cats and the Hyænas is the curious Aardwolf (*Proteles Lalandii*) of South Africa, the sole representative of the family of the *Protelidæ*.

The Aardwolf is a nocturnal, burrowing animal, about as large as a Fox, of a yellowish-grey colour, with black stripes on the sides, the snout prolonged, and the ears large and pointed. It has five toes on the fore-feet and four on the hind-feet (as in Dogs), and resembles the Hyænas in having a stiff mane on the neck and back. The skull and teeth are of the Viverrine type.

The family of the *Hyænidæ* includes only the Hyænas, all of which are confined to the Old World. The Hyænas are digitigrade, but the claws are non-retractile, and all the feet have only four toes each. The tongue is rough and prickly, and the pupil of the eye is vertical. The hind-legs are shorter than the fore-legs, so that the trunk sinks towards the hind-quarters. The hair is coarse and bristly, with a stiff mane on the neck; and the tail is bushy. The head is extremely broad, the muzzle rounded, and the muscles of the jaws extremely powerful. The skull has the sagittal crest so greatly developed as to give it an almost pyramidal form, and the zygomatic arches are exceedingly wide. All the præmolars and molars are trenchant, except the single upper molar, which is very small and has a tuberculate crown. The carnassials are of great size (fig. 528), the upper carnassial (4th præmolar) having a large internal tubercle, against which the wholly trenchant lower carnassial (1st molar) bites. The dental formula is—

$$i\,\frac{3-3}{3-3};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{4-4}{3-3};\quad m\,\frac{1-1}{1-1}=34.$$

All the known species of Hyæna are confined to the warmer regions of the Old World. The Striped Hyæna (*H. striata*) is found in North

Africa, Asia Minor, Arabia, and Persia, ranging into India. The Spotted Hyæna (*H. crocuta*) occurs all over Africa, south of the Sahara; and the Brown Hyæna (*H. brunnea*) is also found in the south of Africa.

The last family of the *Æluroidea* is that of the *Felidæ*, or "Cats," in the wide sense of the term; comprising the Lion,

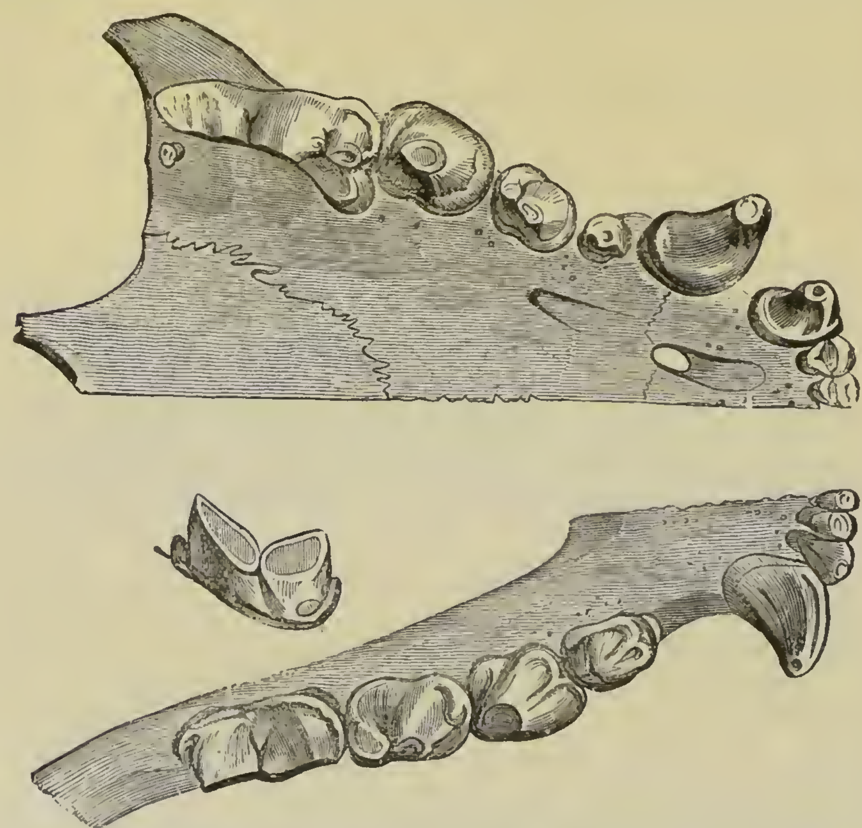


Fig. 528.—Dentition of the Spotted Hyæna, half the natural size. The upper figure gives the upper jaw, and the lower figure the mandible, on one side.

Tiger, Jaguar, Leopard, Lynxes, Domestic Cat, &c. All the members of this family are completely digitigrade, the soles of the feet being hairy, and the whole of the metacarpus and metatarsus being raised off the ground.

The legs are of nearly equal size, and the hind-feet have only four toes each, whilst the fore-feet have five. All the toes are furnished with strong, curved, retractile claws, which, when not in use, are withdrawn within sheaths by the action of elastic ligaments, so as not to be unnecessarily blunted. The ungual phalanges (fig. 529) are strongly bent near their middle, and the resistance of the ligaments which retract the claws is overcome (when the claws are to be protruded) by the contraction of the *flexor profundus perforans*. All the Cats are

exceedingly light upon their feet, and they all have the habit of seizing their prey by suddenly springing upon it.

The skull of the *Felidæ* (fig. 530) is remarkable for the shortening of the facial region. Owing to this, and to the great

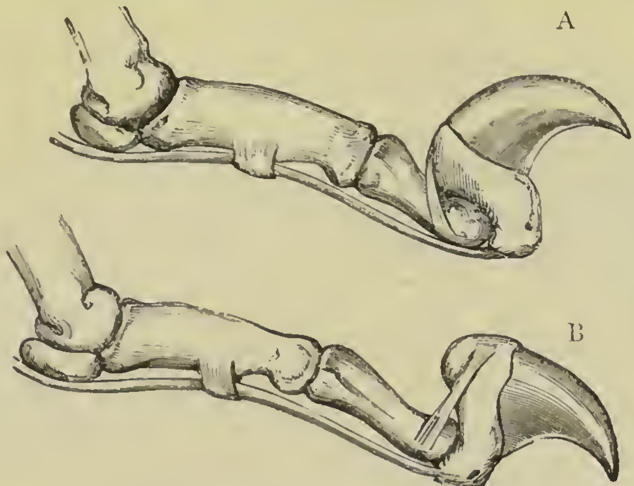


Fig. 529.—Bones and ligaments of the toe of a Cat, showing the claw retracted (A) and protruded (B). After T. J. Parker.

size of the muscles concerned in mastication, the head assumes a short and rounded form, with an abbreviated and rounded muzzle. The zygomatic fossæ are enormously expanded, and the sagittal crest is only less than it is in the Hyænas. The condyles of the lower jaw are transversely

Fig. 530.—Side view of the skull of the Lion (*Felis leo*).

elongated, and are locked by ligaments in the glenoid cavities, the anterior and posterior edges of which project in such a way as to entirely preclude rotatory movements. The molars and præmolars collectively (fig. 514) are fewer in number than in any other of the *Carnivora* (hence the shortness of the

jaws), and they are all trenchant, except the single molar in the upper jaw, which is very small and is tuberculate. The upper carnassial has three lobes, and a blunt heel or internal process. The lower carnassial has two cutting lobes, and no internal process. The dental formula is—

$$i\,\frac{3-3}{3-3};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{2-2};\ m\,\frac{1-1}{1-1} = 30.$$

Lastly, the tongue in the *Felidæ* is roughened and rendered prickly by the presence of horny papillæ, thus rendering it a most efficient rasp in licking the flesh from the bones of the prey; and the pupil of the eye is vertical, and contracts to a line on exposure to light.

It is questionable if any good genera have hitherto been established in this family, as far as recent forms are concerned, and all the living species may be considered as belonging to the single genus *Felis*. The species of *Felis* are found all over the world, except in Australia, New Zealand, the Malayan Archipelago east of "Wallace's line," and the Antilles.

The Lion (*Felis leo*) is too well known to require much special notice. Its colour is always uniform, generally a yellowish or reddish brown; but the young are spotted. The tail is terminated by a tuft of long hairs, and the male is usually furnished with a mane, which is very short, however, in an Indian variety. The Lion is exclusively confined to the Old World, and is an inhabitant of Africa and the south-western parts of Asia. It is doubtful how far any valid species of Lions have as yet been established, but there are several well-marked varieties. The Lion formerly enjoyed a considerably wider range than it has at present; and it is probable that the so-called "Cave-lion" (*Felis spelæa*) of the Pleistocene period is not truly separable as a species from the existing *Felis leo*.

In the Tiger (*Felis tigris*), the tail is without a tuft of hairs at its extremity, and the skin is marked with stripes or spots. The Tiger is a native of southern Asia, but occurs also in Java, Borneo, and Sumatra. The skin is reddish yellow, marked with numerous transverse black stripes. It is a large and powerful animal, and, upon the whole, is probably a more dangerous opponent than even the Lion.

Of the large spotted Cats, the largest is the Jaguar (*Felis onca*), which inhabits South America and the southern parts of North America. It is a very large and powerful animal, and it can both swim and climb with great facility. Another American species is the Puma (*Felis concolor*), in which the colour is uniformly reddish brown. It is exclusively confined to America, ranging from Patagonia to about 60° N. latitude, and though of large size it is a very cowardly animal, and is seldom known to attack man.

The Leopard or Panther (*Felis pardus*) is another well-known species, beautifully spotted, and growing to a length of seven feet inclusive of the tail. It is found all over Africa and Southern Asia, and extends its range to Java and Japan. A nearly allied form is the "Ounce" or "Snow Leopard," which lives at great heights in the mountain-ranges of Central Asia. Another allied form is the Cheetah or Hunting Leopard (*Felis*

jubata) of southern Asia and Africa, which is often raised to the rank of a distinct genus under the name of *Cynælurus*. It has very long legs, and the claws are only imperfectly retractile. Among the smaller spotted Cats may be mentioned the Ocelot (*F. pardalis*), ranging from Mexico to Brazil ; the *Felis viverrina* of India, China, and Malacca ; and the Colocolo (*F. ferox*) of Central America.

Of the smaller *Felidæ*, the best known are the Lynxes, and the Cats, properly so called. Of these, the Lynxes are distinguished by their short tails, and by the fact that the ears are furnished with a pencil of hairs. They differ so much from the other *Felidæ* as to be often placed in a separate genus (*Lyncus*). The best-known species are the European Lynx (*Felis lyncus*), the Caracal (*F. caracal*) of southern Asia and Africa, and the Canadian Lynx (*F. canadensis*) of North America. In the true Cats the tail is long, and the ears are not tufted. The Wild Cat (*Felis catus*) formerly abounded in Britain, but is now almost extinct, though it still occurs in Europe, especially in the Harz and Carpathian Mountains. It is a large and fierce animal, and appears to be quite a match for any man not possessing firearms. The domestic Cat (*Felis domestica*) does not seem to have descended from the wild Cat, and its aboriginal stock is unknown. Probably the various breeds of the Cat, like those of the Dog, have really been derived from more than one wild species. The Cat is known to interbreed freely, not only with the wild Cat, but also with several others of the smaller *Felidæ*, among which may be mentioned the *Felis chaus*, or "Jungle-cat," of India and Africa.

CHAPTER LXXII.

RODENTIA.

Order XIII. Rodentia.—The thirteenth order of *Mammalia* is that of the *Rodentia*, or Rodent Animals, often spoken of as *Glires*, comprising the Mice, Rats, Squirrels, Rabbits, Hares, Beavers, &c.

The Rodents are characterised by the fact that *the two mesial incisors in both jaws are long and curved, growing from permanent pulps, and terminating in chisel-shaped points. Usually only the mesial incisors are present, but a pair of small lateral incisors may also be developed in the upper jaw. There are no canines, and there is a wide interval between the incisors and the molars. There are three true molars on each side of each jaw, and the molars and præmolars are usually four or five in number, their crowns being transversely ridged or tuberculate. The feet are usually furnished with five toes each, all of which are clawed ; and the hallux, when present, rarely differs from the other digits. The placenta is discoidal and deciduate.*

The orbits of the Rodents are not separated from the tem-

poral fossæ, the latter being very small; and the frontals usually have merely rudimentary post-orbital processes. The palate is narrow, and often imperfectly ossified. The most characteristic point, however, about the Rodents is to be found in the structure of the incisors, which are adapted for continuous gnawing, and which have persistent pulps, so that they continue to grow throughout the life of the animal. The two central incisors in both jaws are large, long, and curved, prismatic in section, and forming segments of a circle (fig. 531).

Fig. 531.—A, Side view of the skull of *Cynomys Ludovicianus*; B, Molar teeth of the upper jaw of the Beaver (*Castor fiber*). (After Giebel.)

In most of the Rodents (*Simplicidentata*) there are only the two median incisors in each jaw; but in the Hares and Rabbits (*Duplicidentata*) there is an additional pair of small upper incisors placed behind the large central pair. The front face of the incisors is covered by a plate of hard enamel, while the hinder part of the tooth is composed only of the comparatively soft dentine, sometimes (Duplicidentate Rodents) covered by an exceedingly thin layer of enamel. This being the structure of the incisors, it follows that when the tooth is exposed to attrition, the soft dentine behind wears away more rapidly than the hard enamel in front. The result of this is that the crown of the tooth acquires by use a chisel-like shape, bevelled away behind, and the enamel forms a persistent cutting-edge.

The gnawing action of the incisors is assisted by the articulation of the lower jaw, the condyle of which is placed longitudinally and not transversely, so that the jaw slides backwards and forwards. The molars, consequently, have flat crowns (fig. 531, B), the enamelled surfaces of which are always arranged in transverse ridges, in opposition to the antero-posterior movements of the jaw. (It is convenient in the case

of the Rodents to use the term "molars" for the entire series of the back teeth.)

The intestine in the Rodents is very long, and the cæcum voluminous (rarely wanting). The brain is nearly smooth, and without convolutions. The Rodents are almost all small animals, and they are mostly very prolific. They subsist principally, in many cases entirely, upon vegetable matters, especially the harder parts of plants, such as the bark, roots, or seeds. In cold climates they generally hibernate.

In *space* the Rodents have an all but universal distribution, only the oceanic islands of the Pacific being without indigenous forms. As regards their distribution in *time*, a very large number of fossil Rodents have been recognised as occurring in Tertiary and Post-tertiary deposits. The Rodents of the Eocene Tertiary are largely referable to extinct types, but there are forms of such living genera as *Sciurus* and *Myoxus*, while the Marmots are represented by *Plesiarctomys*. In the Miocene and Pliocene we meet with representatives of the Squirrels, Dormice, Porcupines, Calling Hares, &c. *Cricetodon* is nearly related to the existing Hamsters; while *Chalicomys* and *Steneofiber* represent the Beavers. These last are represented in the Post-tertiary deposits of Europe by *Trogontherium*, and in corresponding deposits in North America by the huge *Castoroides*, which seems to have been equal to a bear in size.

In accordance with the number of the incisor teeth, the Rodents may be divided into the two divisions of the *Simplicidentata* and *Duplicidentata*. In the former of these, comprising all the ordinary Rodents, there are only two upper incisors. In the latter, comprising only the Hares and Rabbits and the Calling Hares, there are two rudimentary upper incisors behind the large central incisors.

I. Simplicidentata.

The Rodents comprised in this division have only two upper and two lower incisors, and these are enamelled in front only. The fibula does not articulate with the os calcis.

The Simplicidentate Rodents have been divided by Mr Alston into the three groups of the *Sciuromorpha*, *Myomorpha*, and *Hystricomorpha*, collectively including a large number of families, only the more important of which can be noticed here, and that only in the briefest manner.

Section i. Sciuromorpha.—The Squirrel-like Rodents included in this section have complete clavicles; the fibula is separate from the tibia; the zygomatic arch is formed by the malar bone, unsupported by a process from the maxilla; there

are four lower "molars," and generally four or five upper molars; the tail is generally hairy, and the upper lip is usually cleft. The two most important families included under this head are the *Sciuridæ* (Squirrels and Marmots) and the *Castoridæ* (Beavers).

In the family of the *Sciuridæ* the molars are rooted, five in number in the upper jaw on each side (the first being often deciduous), and four on each side of the lower jaw; their crowns, when unworn, being tuberculate.

The true Squirrels (*Sciurus*) are familiarly known in the person of the common British species (*Sciurus vulgaris*), and the equally common Grey Squirrel (*S. cinereus*) of the United States. Numerous species (about one hundred in number) more or less closely allied to these occur in other countries, and they are especially abundant in North America.

In the genera *Pteromys* and *Sciuropterus*, or "Flying Squirrels," there is a peculiar modification by which the animal can take extended leaps from tree to tree. The skin, namely, extends in the form of a broad membrane between the hind and fore legs, and this acts as a kind of parachute, supporting the animal in the air. There is, however, no power whatever of true flight, and the structure is identically the same as that which we have previously seen in the Flying Phalangers (*Petaurus*), which take the place of the Flying Squirrels on the Australian continent. The Flying Squirrels are found in southern Asia, Polynesia, the north-east of Europe, Siberia, and North America.

Intermediate between the typical Squirrels and the Marmots are the Ground-squirrels (*Tamias*) of Europe, Asia, and North America. An extremely familiar example of this genus in the United States and Canada is the common Chipmunk (*T. striatus*).

The Marmots (*Arctomys*), unlike the true Squirrels, are terrestrial in their habits, and live in burrows, having short tails, thick bodies, and short legs. There are numerous species of this family inhabiting various parts of Europe and northern Asia, and generally distributed over the whole of North America. Good examples are the Alpine Marmot (*A. marmota*) of the mountain-ranges of Central Europe, and the "Wood-chuck" (*A. monax*) and "Whistler" (*A. pruinosus*) of North America. Another well-known American type is the Prairie-dog (*Cynomys ludovicianus*), which lives in communities in the prairies lying to the east of the Rocky Mountains.

Also belonging to the present family are the Pouched Marmots (*Spermophilus*), which possess cheek-pouches, and are widely distributed over North America, northern Europe, and northern Asia.

The family of the *Castoridæ* is represented only by the Beaver (*Castor fiber*, fig. 532), distinguished by the possession of four "molars" on each side of each jaw, the hind-feet being webbed, and the tail flattened and scaly. The fore-feet are smaller than the hind-feet, and all the feet are furnished with five unguiculate toes.

The Beaver is a large Rodent, attaining a length of from two and a half to three feet. Naturally it is a social animal, living in societies, and this is still the case in America,* but in northern Europe and Asia, where the animal has been much hunted, it usually leads a solitary life. When living in social communities the Beavers build dams across the rivers, as well as

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* The American Beaver is sometimes considered to be a distinct species (*Castor canadensis*).

habitations for themselves, by gnawing across the branches of trees or shrubs, and weaving them together, the whole being afterwards plastered with mud. There is no doubt but that the Beaver shows extraordinary ingenuity in these and similar operations; but there can be equally little

Fig. 532.—The Beaver (*Castor fiber*).

doubt as to the greatly-exaggerated stories which have been set afloat in this connection. The tail is greatly flattened and scaly, and the animal gives the alarm by striking it upon the water. The Beaver is hunted chiefly for the sake of the skin, but also for the substance known as *castoreum*. This is a fatty substance, secreted by the preputial glands, and employed as a therapeutic agent.

SECTION 2. MYOMORPHA.—The Mouse-like Rodents included in this section have generally complete clavicles; the zygoma is formed partly by the malar bone and partly by the maxilla; the tibia and fibula are more or less extensively anchylosed with one another; there are usually three molars on each side of each jaw; the tail is often scaly; and the upper lip is usually cleft. The principal families included in this section are those of the *Myoxidæ* (Dormice), *Muridæ* (Mice and Rats), *Spalacidæ* (Mole-rats), *Geomyidæ* (Pouched Rats), and *Dipodidæ* (Jerboas).

The family of the *Myoxidæ* includes the familiar little Rodents known as "Dormice," which are in many respects intermediate between the Mice and the Squirrels. The "molars" in this family have roots, and are four in number on each side; the tail is long and hairy; the pollex is rudimentary; and the hind-feet are five-toed. The intestine is destitute of a cæcum. The known species, to the number of about a dozen, are all confined to the Old World; and the graceful little *Myoxus avellanarius* is found in Britain.

The family of the *Muridæ* is an extremely large one, and includes the Rats, Mice, Hamsters, Voles, Lemmings, &c. In this family the tail is long, always thinly haired, often naked and scaly. The lower incisors are compressed and pointed; and the molars are rootless, usually three in number on each side, rarely two in the lower jaw, or in both, or four in both. The pollex is rudimentary, and the hind-feet are five-toed.

The *Muridæ* are distributed over almost the whole world, except the islands of the Pacific, about three hundred living species being known, and some of the species (such as the Brown Rat and Common Mouse) are similarly cosmopolitan in their range.

The Black Rat (*Mus rattus*), Brown Rat (*M. decumanus*), Common Mouse (*M. musculus*), Field-mouse (*M. sylvaticus*), and Harvest-mouse (*M. minutus*) are familiar European examples of the type-genus *Mus*. The first three of these are equally common in America, but are not indigenous there. Most of the indigenous Mice of North America belong to the genus *Hesperomys*.

The Hamsters (*Cricetus*) differ from the Mice and Rats principally in the possession of cheek-pouches opening into the mouth. They are confined to the Old World, a well-known European species being the *Cricetus frumentarius*.

The Gerbilles (*Gerbillus*) are separated from the true Mice by the great length of the hind limbs, which are adapted for jumping. They live in Africa, the south-east of Europe, and southern Asia.

The Voles (*Arvicola*) are mostly rat-like in form, with a moderately hairy tail and short ears. They have the molars composed of alternating triangular prisms (fig. 533). Of the genus *Arvicola* itself about fifty species

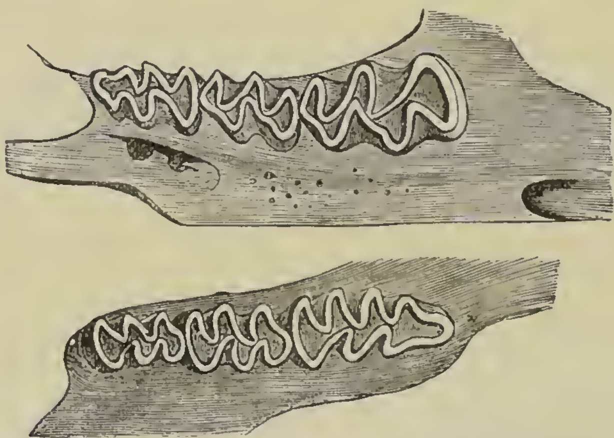

Fig. 533.—Molar teeth of the Water-rat (*Arvicola amphibius*).

are known, the two most familiar of the three British species being the Water-rat (*A. amphibius*), which ranges from western Europe to China, and the Field Vole (*A. agrestis*).

Allied to the preceding is the Musquash or Ondatra (*Fiber zibethicus*) of North America, which leads a semi-aquatic life, and has the tail compressed and the hind-feet partially webbed. From its possession of glands producing a musky secretion, it is often called the "Musk-rat."

One of the most interesting of the *Muridæ* is the Lemming (*Myodes lemmus*), which inhabits the mountainous parts of Scandinavia. It is chiefly remarkable for migrating at certain periods, generally towards the approach of winter, in immense multitudes and in a straight line, apparently in obedience to some blind mechanical impulse. In these journeys the Lemmings march in parallel columns, and nothing will induce them to deviate from the straight line of march, the migration always terminating in the sea, and ending in the drowning of all that have survived the journey.

The family *Geomyidæ* comprises the so-called Pouched Rats and Gophers of North America, distinguished by the possession of a pair of extraordinary

pouches, which differ from ordinary cheek-pouches in opening *outside* the mouth, and in being lined with a fine fur, and which are apparently used for carrying provender. Some of the members of this family (*Geomys* and *Thomomys*) have the fore-feet greatly developed and adapted for burrowing; whilst the so-called "Kangaroo-rats" (*Dipodomys*) have very long hind-limbs, and the fore-limbs are not specially developed. One of the best-known species of this family is the common Pocket-gopher (*Geomys bursarius*) of the Mississippi Valley and Canada.

Nearly related to the Gophers of North America are the Mole-rats (*Spalacidæ*) of the Old World. These have a thick body, a broad flat head, short legs, the tail rudimentary or absent (fig. 534), the molars

Fig. 534.—The Mole-rat (*Spalax typhlus*).

rooted, and the feet pentadactylous. They do not possess the peculiar external food-pouches of the preceding group. The ears are very small, and may be wanting; and the eyes are very minute, and may be covered by the skin, so as to be functionally useless. The Mole-rats are all burrowing animals, living upon vegetable substances. The true Mole-rat (*Spalax typhlus*, fig. 534) inhabits Eastern Europe and South-western Asia, and is quite blind. *Georychus* and *Bathyergus* are African forms of this group.

The last family of the Myomorph Rodents which needs notice here is that of the *Dipodidæ* or Jerboas, mainly characterised by the disproportionate length of the hind-limbs as compared with the fore-limbs. The tail also is long and hairy, and there are complete clavicles. The Jerboas

live in troops, and owing to the great length of the hind-legs, they can leap with great activity and to great distances. They are all of small size, and inhabit Russia, North Africa, and North America. The best-known members of this family are the common Jerboas (*Dipus ægyptiacus*) of Africa and South-western Asia, which live in societies and construct burrows; he Jumping Hare (*Pedetes capensis*) of South Africa; and the Jumping Mouse (*Zapus hudsonicus*) of North America.

SECTION 3. HYSTRICOMORPHA.—The section of the Porcupine-like Rodents is characterised by having the zygomatic arch formed by a stout malar bone, unsupported by the maxilla; the clavicles are complete or incomplete; the fibula is distinct from the tibia; there are four molars on each side in each jaw (reduced to three in a species of *Ctenodactylus*); and the upper lip is usually not cleft. The principal families included in this section are those of the *Octodontidæ* (Spiny Rats, &c.), the *Hystricidæ* (Porcupines), the *Chinchillidæ* (Chinchillas, &c.), the *Dasyproctidæ* (Agoutis and Pacas), and the *Caviidæ* (Cavies and Guinea-pigs).

The family of the *Octodontidæ* includes a large number of Rodents which are principally South American and African (*Octodon*, *Echimys*, *Ctenomys*, &c.) A well-known species is the beaver-like Coypu (*Myopotamus coypus*) of South America, in which the hind-feet are webbed, and the tail is long and rounded. It inhabits burrows in the sides of streams, and it leads a semi-aquatic life. Among the other *Octodontidæ*, the species of *Octodon* live in South America, and are rat-like Rodents, with short tufted tails, the molars being, typically, of a simple type. In *Ctenomys*, also South American, the toes of the hind-feet carry laterally a sort of comb of bristles. The Spiny Rats (*Echimys*) are found in the West Indies and in Africa, and have the hair mixed with fine spines, while the molars have complicated enamel-folds. *Petromys* is an African type.

In the family of the *Hystricidæ* are the well-known "Porcupines," characterised by the fact that the body is always more or less extensively furnished with longer or shorter hollow spines or prickles. The true Porcupines (*Hystrix*) have non-prehensile tails, generally long spines, and imperfect clavicles. They are terrestrial in their habits, and are well exemplified by the common Porcupine (*H. cristata*), which inhabits Southern Europe and North Africa. It is a burrowing nocturnal animal. Other species inhabit Southern Asia and India. In the allied genus *Atherura* the tail is elongated and scaly, and is terminated by a bundle of flattened bristles. The known species of this genus inhabit Siam and Malacca, and western Africa.

The American Porcupines or Tree-porcupines differ from the preceding in being adapted for an arboreal life, having complete clavicles. The tail may or may not be prehensile. The genus *Sphingurus* (*Cercolabes*) is wholly restricted to the Neotropical region, and is characterised by the fact that the tail is prehensile. The genus *Erethizon* differs from the preceding in the fact that the tail is non-prehensile. It is represented by the well-known Canada Porcupine (*E. dorsatum*), in which the quills are short and half hidden in the hair.

The family of the *Chinchillidæ* is exclusively South American, and comprises only the Chinchillas and Viscachas—small nocturnal animals which

are strictly terrestrial in their habits, and have the hind-legs longer than the fore-legs. The incisors are short, and the molars rootless. The true Chinchillas (*Lagidium*) are squirrel-like, with an exceedingly soft fur. They live in the Andes, extending up to an elevation of 16,000 feet. The Viscacha (*Lagostomus trichodactylus*) is more like a Marmot in appearance, and inhabits the great plains of southern South America, living in burrows in the ground.

In the family of the *Dasyproctidæ* are the Agoutis and Pacas, characterised by having long incisors, molars at first rootless, but afterwards rooted, rudimentary clavicles, and five-toed fore-feet. The Agouti (*Dasyprocta aguti*, fig. 535) is found in Guiana, Brazil, and Peru. Its fore-feet are five-toed, but the hind-feet have only three toes. Other species of *Dasyprocta* inhabit South America and the West Indian islands.

Fig. 535.—The Agouti (*Dasyprocta aguti*).

The Paca (*Cœlogenys paca*) has five toes on both the hind and fore feet. It has the zygomatic arches enormously inflated, the maxillary portion being hollowed out into chambers which are lined by mucous membrane, and open into the mouth, and the use of which is quite unknown. It inhabits Central and South America.

In the family of the *Caviidæ*, the tail is rudimentary; the incisors are short; the back teeth are rootless; the clavicles are rudimentary or wanting; the feet are, typically, three-toed, and the claws are in the form of hoof-like nails. They are all South American. The Capybara (*Hydro-*

chœrus capybara) is the largest of living Rodents, attaining a length of three or four feet. It leads a semi-aquatic life, and has the feet incompletely webbed. The *Cavia aperea* has short legs and ears, and is believed to be the parent stock of the domesticated Guinea-pigs; while other species of Cavy are also found in South America.

II. Duplicidentata.

In the section of the Duplicidentate Rodents, including only the Hares, Rabbits, and Calling Hares, there are only two lower incisors, but there are *four* upper incisors. The two median upper incisors are, as in Rodents generally, the functional incisors, but behind these are two small and functionally useless lateral incisors. At birth there is the full number of upper incisors—viz., three on each side of the jaw—but the outermost pair disappear immediately. Not only are the Duplicidentate Rodents distinguished by having an extra pair of upper incisors, as compared with the Simplicidentate forms, but the incisors have a complete covering of enamel, which, however, is exceedingly thin upon the lateral and posterior aspects of the tooth. An additional character of this section is that the fibula always articulates with the os calcis.

The family of the *Leporidæ* includes the Hares and Rabbits, distinguished by the disproportionate length of hind-legs as compared with the fore-legs, the latter having five digits, while the former are tetradactylous. The clavicles are imperfect. The orbits communicate from side to side, by the confluence of the optic foramina. The tail is short and erect. The dental formula is—

$$i\,\frac{2-2}{1-1};\ c\,\frac{0-0}{0-0};\ pm\,\frac{3-3}{2-2};\ m\,\frac{3-3}{3-3}=28.$$

The common Hare (*Lepus europæus*) ranges over the whole of Europe, with the exception of Northern Scandinavia. Its place in this latter country is taken by the Mountain Hare (*Lepus timidus* or *L. variabilis*), which becomes white in winter. This species also occurs in Scotland and in Iceland, and the *Lepus glacialis* of the Arctic regions seems to be only a variety of it. Of the American Hares the commonest is the *Lepus americanus*, which ranges from the barren grounds in the north to New Mexico in the south, and also turns white in winter. The Rabbit (*L. cuniculus*) appears to have been originally a native of Mediterranean region, but has become naturalised over a large part of Europe.

The family *Lagomydæ* includes only the Calling Hares or Pikas (*Lagomys*), which differ from the true Hares in having legs of nearly equal length, no visible tail, and short ears, thus resembling Guinea-pigs in aspect. They have only five back teeth on each side of the upper jaw (instead of six); and the clavicles are complete. The Calling Hares inhabit Russia and the whole of Northern Asia, and a single species occurs in the Rocky Mountains.

CHAPTER LXXIII.

CHEIROPTERA.

ORDER XIV. CHEIROPTERA. — This order is an extremely natural one, and includes only the Bats. *The anterior limbs are longer than the posterior, and the digits of the manus, with the exception of the pollex, are greatly elongated, and are united by an expanded fold of the skin, or "patagium," which extends from the fore-limbs to the hind-limbs and sides of the body, and is used in flight. The three outermost digits of the hand, and generally the index also, are clawless. The clavicles are complete; the sternum is keeled; and the ulna and fibula are rudimentary. There are two mammary glands, and these are pectoral in position. The placenta is discoidal.*

The *Cheiroptera* are essentially distinguished from all the other Mammals by their possession of the power of flight. The apparatus of flight in the Bats consists of a "patagium," or flying membrane, in the form of a fold of the skin which is supported upon the much-elongated four outer digits of the manus (fig. 536), and is prolonged from the hand and arm to the side of

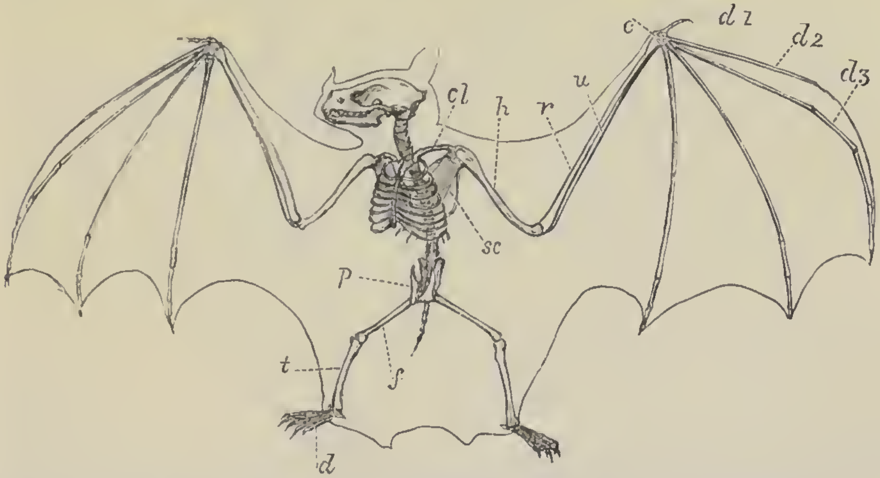

Fig. 536.—Skeleton and outline of Bat (*Phyllostoma hastatum*). d_1 Thumb; d_2 Fore-finger; d_3 Middle finger; *sc* Scapula; *cl* Clavicle; *f* Femur; *t* Tibia; *d* Toes.

the body and hind-limb, very often passing between the hind-limbs, so as to form an "inter-femoral membrane" in which the tail may be included. The patagium is hairless or nearly so.

The bones in the Bats are not pneumatic. The orbits are not separated from the temporal fossæ. The præmaxillæ are

small or rudimentary. The cervical vertebræ are of unusual size; and the caudal region of the spine may be well developed, or may be rudimentary. Teeth of three kinds are always

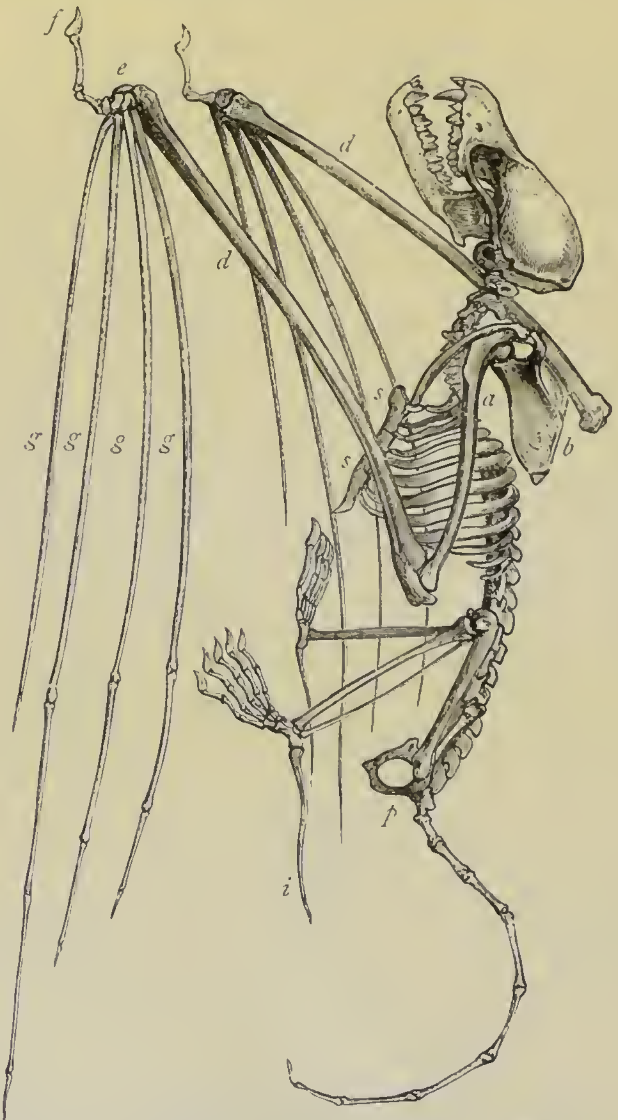

Fig. 537.—Skeleton of the Mouse-coloured Bat (*Vespertilio murinus*). *a* Humerus; *b* Scapula; *d* Radius, with the rudimentary ulna at its proximal end; *e* Carpus; *f* Thumb; *g g* Metacarpal bones; *s s* Sternum; *p* Pelvis; *i* Supplementary bone attached to the calcaneum.

present in the dentition, and the canines are always well developed (fig. 538). The molars are tuberculate or grooved in the frugivorous Bats, and are cuspidate in the insectivorous species.

The most striking features in the structure of the *Cheir-*

optera are, however, those connected with the conformation of the limbs (fig. 537). The fore-limb is larger than the hind-limb, the strong and moderately long humerus articulating with a very large scapula. The clavicles are complete, and the sternum is keeled. The radius is long and well developed, but the ulna is reduced to a mere splint-bone, which is anchylosed with the proximal end of the radius, all power of rotation of the fore-arm being thus lost. The thumb is short, and its last phalanx carries a claw. The index is long, but is shorter than the other digits, and often consists of its metacarpal only, in other cases with two short phalanges in addition. It is usually clawless, but may (as in most of the *Pteropodidæ*) be unguiculate. Of the remaining digits the medius is the longest; and all are clawless, and possess two or three phalanges.

In the hind-limb, the fibula is incomplete, and the foot is furnished with five clawed toes. To the os calcis is attached, in most Bats, a cartilaginous or bony process or spur, which is directed inwards along the lower margin of the inter-femoral membrane, and serves to put this upon the stretch during flight.

The Bats are all crepuscular and nocturnal in their habits, and are sometimes carnivorous, sometimes frugivorous. The eyes are small, but the ears are very large, and the sense of touch is most acute. During the day they retire to caves or crevices amongst the rocks, where they suspend themselves by means of the hind-feet, which are provided with curved claws. In their flight, though they can fly in the genuine and proper sense of the term, and can turn with great ease, they are by no means as rapid and as active as are the Birds. Upon the ground they progress with some difficulty, dragging themselves along by means of the hooked thumbs. In temperate or cold regions the Bats hibernate.

As regards their *distribution in space*, the Bats may be said to have a cosmopolitan range. About four hundred species are known, and the largest number of these are found within the tropics. The Fox-bats (*Pteropodidæ*) are characteristic of Australia and of the warm regions of the Old World, but do not occur in North or South America. The Horse-shoe Bats (*Rhinolophidæ*) are also totally wanting in the New World. On the other hand, the Vampire Bats (*Phyllostomidæ*) are wholly confined to the New World, and, with the exception of a single species, are restricted to the Neotropical province.

As regards their *distribution in time*, the *Cheiroptera* date from the Upper Eocene, but the fossil forms present no points of special interest.

The order *Cheiroptera* may be divided into the two sections or sub-orders of the *Megacheiroptera*, or Fruit-eating Bats, and the *Microcheiroptera*, or Insect-eating Bats.

MEGACHEIROPTERA.

SUB-ORDER I. MEGACHEIROPTERA (FRUGIVORA). — This section comprises comparatively large forms of the Bats, which are essentially frugivorous, and in which the molars are marked with a median longitudinal groove. As an almost universal rule, the index digit of the manus is furnished with a claw. The tail is rudimentary, and the nose is not furnished with leaf-like appendages.

This section includes only the single family of the *Pteropodidæ* (Fox-bats), all the species of which are confined to Australia and to the warmer parts of the Old World.

The "Fox-bats" or "Flying Foxes" are so called from the long and pointed muzzle, which gives them somewhat the appearance of a fox as regards the head. The ears in these Bats are simple and of moderate size, and the nose is not disfigured by membranous appendages (fig. 538).

Fig. 538.—Head of *Pteropus jubatus*, of the natural size.

Though essentially frugivorous, the Fox-bats possess pointed canines, and do not altogether refuse to eat small animals. Their principal food, however, consists of fruits, and, in accordance with this, the molars are tuberculate or grooved, and the intestine is of considerable comparative length. Not only is the pollex clawed, but the index, with hardly an exception, is so also. The tail is rudimentary or wanting, and the inter-femoral membrane is much reduced in size. About seventy species of Fruit-bats are known, the principal genus being *Pteropus* itself. They are the largest of the Bats, the Kalong (*Pteropus edulis*) attaining a length of four feet or more from the tip of one wing to that of the other.

MICROCHEIROPTERA.

SUB-ORDER II. MICROCHEIROPTERA (INSECTIVORA).—This section of the *Cheiroptera* comprises insect-eating or blood-sucking Bats, in which the molar teeth are furnished with sharp cusps. The index-finger of the manus is never clawed, and the tail is of considerable length. Very often the nostrils are surrounded by membranous, leaf-like processes. This section is divided by Mr Dobson into the five families of the *Rhinolophidæ* (Horse-shoe Bats), *Nycteridæ*, *Vespertilionidæ*, *Emballonuridæ*, and *Phyllostomidæ* (Vampire Bats), the characters of which are briefly given below.

Fam. 1. *Rhinolophidæ.*—This family includes the "Horse-shoe Bats," so called from the possession of foliaceous or membranous expansions of the skin which surround the nostrils. There is only a single upper incisor and two lower incisors on each side. The ears are large, but have no tragus or "earlet." The Horse-shoe Bats are entirely confined to the Old World, and are all of small size. The principal genus is *Rhinolophus* itself, of which there are two British species—the greater and lesser Horse-shoe Bats (*R. ferrum-equinum*) and (*R. hipposideros*).

Fam. 2. *Nycteridæ.*—The small group of Bats included under this head is nearly related to the preceding, as shown by their possession of similar leaf-like nasal appendages. The ears, however, are of exceptionally large size, more or less united with one another along their inner margins (fig. 539), and having the tragus developed so as to form an "earlet." The middle digit of the hand possesses two phalanges.

The Bats of this family are inhabitants of the warmer parts of the Old World (India and Africa principally), the chief genus being *Megaderma*.

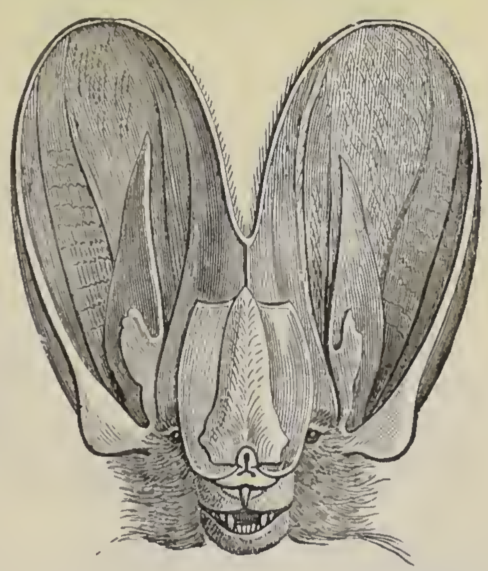

Fig. 539.—Head of *Megaderma frons*, showing the leaf-like nasal appendages and the large and partially united ears, with their internal earlets.

Fam. 3. *Vespertilionidæ.*—This family includes a large number (about one hundred and sixty species) of small insectivorous Bats, which may be regarded as the most typical members of the order *Cheiroptera*. In their dentition they nearly approach the order of the Insectivorous Mammals, the molar teeth being furnished with small pointed eminences or cusps, adapted for crushing insects, and the incisors being of small size. The nose is not furnished with leaf-like appendages, and the tail is elongated, and enclosed in a large inter-femoral membrane (fig. 540). The species of

this family are generally distributed over the temperate and warm regions of both the Old and New Worlds. About fifteen species of this family have been described as British, but of these only two are at all common. Of

Fig. 540.—*Vespertilio discolor*, one-half the natural size.

these, the Pipistrelle (*Vesperugo pipistrellus*) is the commonest, occurring over the whole of Britain. The Long-eared Bat (*Plecotus auritus*) is also not uncommon, and is distinguished by its greatly elongated ears, which are confluent above the forehead. The largest British species is the Noctule (*Vesperugo noctula*), which measures as much as fifteen inches in expanse of wing.

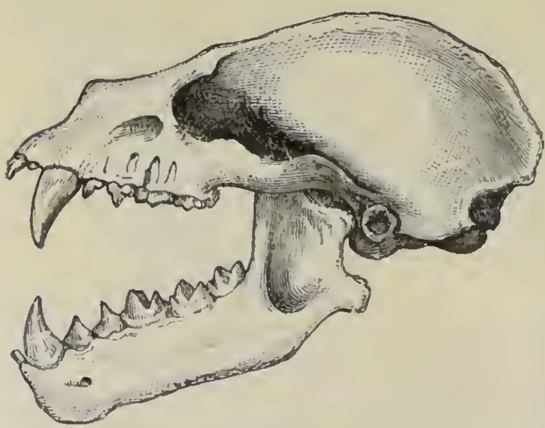

Fig. 541.—Skull of the Javelin Bat (*Phyllostoma hastatum*), showing the large canines and cuspidate molars.

Fam. 4. *Emballonuridæ.*—The Bats included in this group have thick legs, with the fibula better developed than usual. The nose is almost always wholly destitute of leaf-like appendages. The tail is included in the inter-femoral membrane towards its base, but it perforates this membrane at or about its middle, and generally exhibits a longer or shorter free terminal portion. The members of this family are all insectivorous, and they are mostly inhabitants of the warmer regions of both the Old and New Worlds.

Fam. 5. *Phyllostomidæ.*—This family includes the so-called "Vampire Bats," and is wholly confined to the New World, being, with the exception of a Californian species, entirely restricted to South America, Central America, Mexico, and the West Indies. The nose is furnished in the Bats of this family with leaf-like appendages, which, however, are sometimes rudimentary; and the middle finger of the hand possesses three phalanges (instead of two as in Bats generally). The præmaxillæ are well developed, and the canines are of large size and pointed (fig. 541). Some of the *Phyllostomidæ* are insect-eaters, and others live on fruits; but some of them have the habit of sucking the blood of sleeping animals, occasionally attacking man himself. This habit has been ascribed to the great Javelin Bat (*Phyllostoma hastatum*, fig. 541); and there can be no doubt as to the correctness of this charge in the case of the extraordinary genus *Desmodus*, in which the adult has only two upper incisors, which are of exceedingly large size and sharp-edged, and are used for making an incision in the skin from which the blood may be sucked. The great Javelin Bat has an expanse of wing of nearly two feet, and some of the other members of this family are nearly as large.

CHAPTER LXXIV.

INSECTIVORA.

ORDER XV. INSECTIVORA.—This order comprises a number of small Mammals which are very similar to the Rodents in many respects, but want the peculiar incisors of that order, and are likewise almost always furnished with clavicles.

In the *Insectivora*, *all the three kinds of teeth are usually present*, *but the exact nature of the dentition varies considerably in different cases. The canines are rarely larger than the incisors*, *and the molars* (fig. 542) *are always serrated with numerous small pointed eminences or cusps*, *adapted for crushing insects. With one exception* (*Potamogale*), *clavicles are always present in a complete form. All the feet are usually furnished with five toes; all the toes are furnished with claws; and the animal walks on the soles of the feet*, *or is more or less completely plantigrade. The hallux is never opposable. The testes pass periodically from the abdomen*

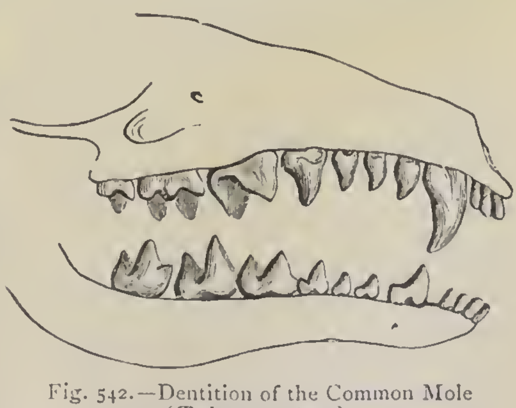

Fig. 542.—Dentition of the Common Mole (*Talpa europæa.*)

into a temporary scrotum; and the placenta is deciduate and discoidal.

The orbits may be complete, but are more commonly confluent with the temporal fossæ. The radius and ulna and tibia and fibula are complete bones, and the latter are usually distinct from one another, though sometimes (*Erinaceus*, &c.) conjoined. The intestine commonly possesses a cæcum, which is sometimes of large size (*Tupaia*); but in other cases (*Soricidæ, Centetes*) a cæcum is wanting. The cerebral hemispheres are small, not covering the cerebellum, and are almost or wholly devoid of convolutions.

The Insectivores are mostly small nocturnal animals, often subterranean in their habits, and generally hibernating in temperate countries. About one hundred and forty living species of the order are known, about half of these being Shrew-mice, and their distribution in space is almost universal. No members of this order, however, are found in Australia or in the continent of South America. The genus *Solenodon*, however, occurs in Cuba and St Domingo, and thus is the sole representative of the *Insectivora* in the Neotropical province. Most of the families of the order are singularly restricted in their range. The Elephant-shrews, *Potamogale*, and the Golden Moles are exclusively African. The *Centetidæ* are inhabitants of Madagascar, but are represented by *Solenodon* in the widely distant West Indies. The Shrew-mice, Moles, and Hedgehogs have the widest range of any of the groups, the first two of these having, in fact, the range of the whole order.

As regards their *distribution in time*, the *Insectivora* appear for the first time in the Eocene, and the existing genus *Talpa* occurs as early as the Miocene.

The order *Insectivora* is generally divided into nine or ten families, the principal characters of which are as follows:—

Fam. 1. *Soricidæ.*—The Shrew-mice are distinguished by having the body covered with hair, and the feet not adapted for digging; whilst there are mostly external ears, and the eyes are well developed. The tail is nearly naked, and scaly; the central upper and lower incisors are very large; the tibia and fibula are united; and there is no cæcum. Of all the *Insectivora*, no division is more abundant or more widely distributed than that of the Shrew-mice, their range extending over North America and the whole of the Old World except Australia.

In general form and appearance, the Shrews very closely resemble the true Mice (*Muridæ*) and the Dormice (*Myoxidæ*), but they are in reality widely different, and must not be confounded with these. The common Shrew (*Sorex vulgaris*), the Garden Shrew (*Crocidura aranea*), and the

Water-shrew (*Crossopus fodiens*), are well-known British species of this family. The smallest known Mammal is the little Etruscan Shrew (*Crocidura suaveolens*) of the countries bordering the Mediterranean, the total length of which, inclusive of the tail, is not more than two and a half inches.

The Desmans or Musk-rats, forming the genus *Myogale*, are sometimes placed here, sometimes in the family of the *Talpidæ*, and are often raised to the rank of a distinct family (*Myogalidæ*). They have the nose prolonged into a kind of flexible proboscis, whilst the feet are webbed, and the tail is compressed, thus adapting the animal for a semi-aquatic life. The hind-feet are much larger than the fore-feet, the small ears are hidden in the fur, and there is a musk-gland at the root of the tail. The central incisors and lateral lower incisors (fig. 543) are very large and pyramidal. The dental formula is—

$$i\,\frac{3-3}{3-3};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{4-4}{4-4};\quad m\,\frac{3-3}{3-3} = 44.$$

The genus *Myogale* is represented by two living species, of which one inhabits south-eastern Russia, while the other is found in the Pyrenees.

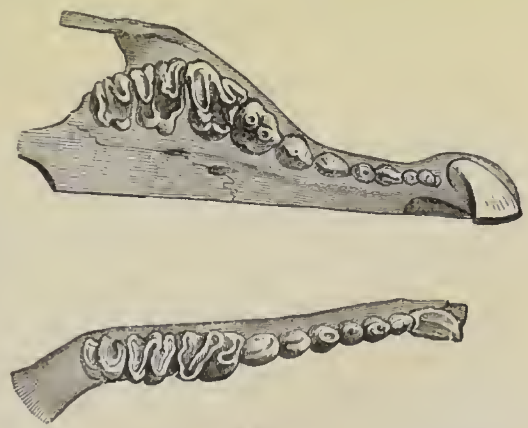

Fig. 543.—Dentition of *Myogale*. The upper figure shows the teeth in the upper jaw, and the lower figure those of the mandible.

Also occupying an intermediate position between the Shrew-mice on the one hand and the Moles on the other hand, is the singular genus *Urotrichus* of Japan. In this genus the nose is long and cylindrical, terminated by a naked fleshy bulb, and extremely sensitive; the tail is moderately developed and hairy; and the fore-feet are adapted for burrowing. A closely allied form (sometimes regarded as a distinct genus) occurs in British Columbia.

Fam. 2. *Talpidæ*.—This family comprises the true Moles, in all of which the body is covered with hair; the feet are formed for digging and burrowing, and the toes are furnished with strong curved claws. There are no external ears; and the eyes in the adult are very small, or may be covered by the skin. The clavicles are strong, the arm very short, the hand wide, and the palm turned outwards and backwards. The fur is short and velvety,. and the tail is generally very short or wanting.

The common Mole (*Talpa europæa*, fig. 544) is the only British species of the family, and is too well known to need much description. The dental formula of the Mole is—

$$i\,\frac{3-3}{3-3};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{4-4}{4-4};\quad m\,\frac{3-3}{3-3}=44.$$

The nearly-allied *Talpa cæca* of Southern Europe has the eyes covered by a membrane, pierced by a small central aperture. Other species of *Talpa* are found in India, China, and Japan.

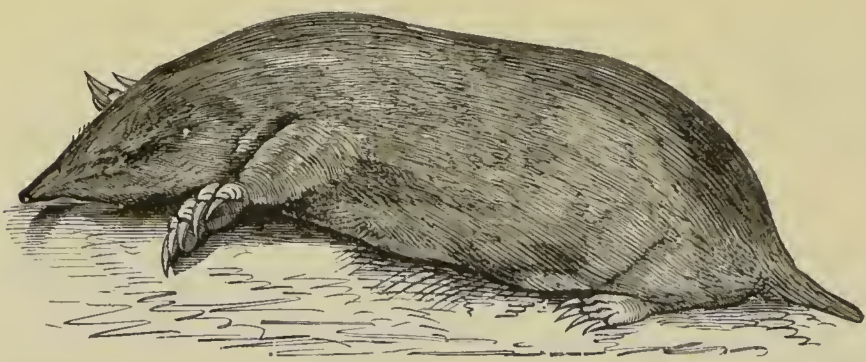

Fig. 544.—European Mole (*Talpa europæa*).

The common Mole (*Talpa europæa*) ranges from Britain to China. The cartilages of the nose in the Mole are strengthened by ossification. The fore-limbs are short and exceedingly strong, the manus broad and shovel-like, and the digits armed with broad flat claws. The radial side of the carpus supports a large sickle-shaped sesamoid bone ("falciform bone"), which supports the pollex in digging. The humerus is excessively short and strong, with great muscular ridges, and it articulates with the short and compressed clavicle and with the long and narrow scapula. The manubrium sterni is long, and its front face is keeled. The hind-feet are comparatively small. The incisors are of small size, and the first lower præmolar is like a canine in form. The eyes, though very small and concealed within the fur, can certainly be used as organs of vision. The subterranean burrows of the Mole are complex, and its food consists chiefly of worms and the larvæ of insects.

The Star-nosed Moles (*Condylura*) are North American, and are distinguished by a fringe of elongated membranous caruncles surrounding the nostrils. The tail is much longer than in the typical Moles; the eyes are very minute; and there are no external ears.

Also North American is the genus *Scalops*, comprising the so-called Shrew-moles. In this genus the tail is short; the muzzle is long, with the nostrils at its extremity; and the eyes are very small and are hidden in the fur. The common Shrew-mole (*Scalops aquaticus*) has the hind-feet webbed, and is found everywhere in the United States east of the Mississippi.

Fam. 3. *Chrysochloridæ.*—This family includes the so-called "Golden Moles," which nearly resemble the true

Moles in form and general habit, but have a fur which is iridescent, and which exhibits beautiful metallic colours. The manus differs from that of the Moles in having the first and fourth digits very small, while the second and third digits are very large, and are armed with immense claws. The clavicles are much more slender, and are longer, than in the true Moles. The eyes are very minute, and are covered by the skin. The dentition is peculiar, and the upper molars (fig. 545) resemble those of the *Centetedidæ* and of *Potamogale* in being V shaped, whereas in the *Insectivora* generally they are W-shaped. The dental formula is—

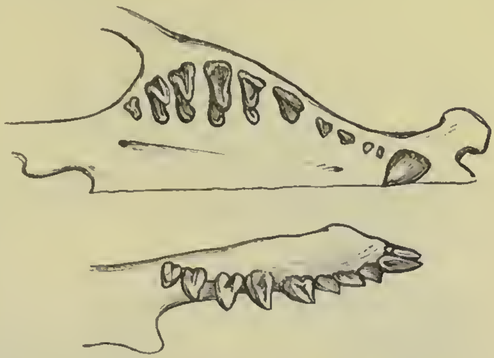

Fig. 545.—Dentition of the Golden Mole (*Chrysochloris*), enlarged. The upper figure shows the teeth in the upper jaw, and the lower figure those of the mandible.

$$i\,\frac{3-3}{2-2};\quad c\,\frac{0-0}{0-0};\quad pm\,\frac{1-1}{3-3};\quad m\,\frac{6-6}{5-5}\ \text{or}\ \frac{5-5}{4-4} = 36 \text{ or } 40.$$

The Golden Moles are peculiar to Africa, ranging from Cape Colony to Mozambique. The best-known species is the *Chrysochloris capensis* of the Cape.

Fam. 4. *Potamogalidæ.*—This family comprises only the single genus *Potamogale*, which contains only a single species —the *Potamogale velox* of West Africa. This is a singular Otter-like Insectivore, which leads an amphibious life, and feeds upon fish. The tail is long and vertically compressed, and there are no clavicles. The animal is only about eighteen inches in length, inclusive of the tail. Its upper molars have the same V-shaped form as is seen in the same teeth in the Golden Moles.

Fam. 5. *Centetidæ.*—This family includes the so-called "Tanrecs" or "Tenrecs" (*Centetes*, &c.) of Madagascar, and the *Solenodon* of the West Indies. The Tanrecs are small animals, somewhat resembling Hedgehogs in appearance and habits, and having the back covered with hair, intermixed with fine prickles, or spiny bristles. The muzzle is long and pointed, and the tail is rudimentary or wanting. The skull is without a zygomatic arch, and the tympanic bones do not form "bullæ." The upper molars have the V-shaped form of the teeth in the two preceding families.

Allied to the genus *Centetes* are the genera *Ericulus*, *Echinops*, and *Geogale*, all of which occur in Madagascar, and of which the last has relationships with the *Soricidæ*. Likewise related to the Tenrecs is the curious genus *Solenodon* of Cuba and Hayti, in which the nose is very long and pointed, the tail is long and scaly, and the body is covered with coarse fur, without spines. The two central incisors of the lower jaw are small, and are placed between long conical lateral incisors which are deeply grooved on their inner surfaces.

Fam. 6. *Erinaceidæ.*—The typical forms of this family are the Hedgehogs (*Erinaceus*), characterised by the fact that the

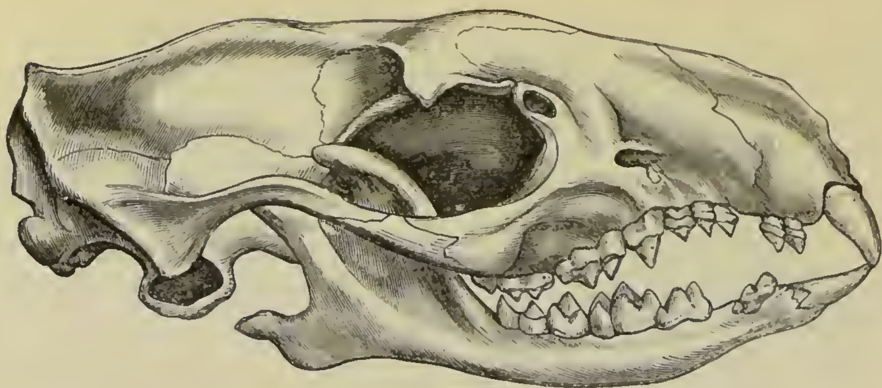

Fig. 546.—Skull of the Common Hedgehog (*Erinaceus europæus*), enlarged.

upper part of the body is covered with prickly spines, the feet are not adapted for digging, and the animal has the power of rolling itself into a ball on the approach of danger. The skull has a complete zygomatic arch, and tympanic bullæ are present. The intestine is without a cæcum. The dental formula of the Hedgehog may be stated to be—

$$i\,\frac{3-3}{2-2};\quad c\,\frac{1-1}{1-1};\quad pm\,\frac{3-3}{2-2};\quad m\,\frac{3-3}{3-3}=36.$$

The teeth regarded as upper canines here are, however, sometimes considered as being the first præmolars, and the lower canines are sometimes regarded as being incisors. The central upper and lower incisors are longer than the others.

The common Hedgehog (fig. 547) inhabits all Europe except Scandinavia and northern Russia, and is nocturnal in its habits. It feeds upon insects, worms, snails, frogs, toads, and snakes. The spines of the young animal are quite flexible and soft, and the adult has the power of rolling itself up into a ball by the contraction of the powerful "orbicularis panniculi" muscle.

Other species of Hedgehogs are found in Asia and in North and South Africa. We may also place here the singular genus *Gymnura*, represented by a single species which inhabits Borneo, Sumatra, and the Malay

Peninsula. In this singular type, the body is covered with long and coarse fur, the tail is long and scaly, the snout is long, and the feet are five-toed.

Fam. 7. *Tupaiidæ.*—The typical forms of this family are the "Banxrings" or "Squirrel-shrews" (*Tupaia*) of India and the

Fig. 547.—The Hedgehog (*Erinaceus europæus*).

Malay Archipelago. These are squirrel-like Insectivores, with long bushy tails, the feet plantigrade, five-toed, with naked soles, and sickle-shaped claws. They climb actively amongst the trees, and also run with facility upon the ground. Closely allied to the *Tupaiæ* is the little *Ptilocercus* of Borneo, in which the tail is very long, and the hairs towards its extremity are arranged like the barbs of a feather.

Fam. 8. *Macroscelidæ.*—This family includes only the little "Elephant-shrews" (*Macroscelides*) of southern and northern Africa. They are readily distinguished by their extraordinarily elongated trunk-like nose, resembling the proboscis of an Elephant, and their very long Kangaroo-like hind-legs.

Fam. 9. *Galeopithecidæ.*—This family comprises only the aberrant genus *Galeopithecus*, which is in some respects intermediate in its characters between the Insectivores and the Lemurs. Only two certainly established species of *Galeopithecus* are known, the *G. volans* of Malacca, Sumatra, and Borneo, and the *G. philippinensis* of the Philippine Islands. The

"Colugos" or "Flying Lemurs," as these animals are often called, are distinguished by the possession of a hairy flying-membrane, or "patagium," in the form of a great lateral fold of the skin which extends from the nape of the neck to the fore-limbs, from these to the hind-limbs, and from these again to the tail. The toes of the hind-feet are also united by a web of the skin, but the manus has the digits free, and in no way specially elongated. Neither the hallux nor the pollex are opposable. The *Galeopitheci* have no power of true flight; but the patagium acts as a parachute, and enables the animal to take extended leaps from tree to tree.

The dental formula of *Galeopithecus* is—

$$i\ \frac{2-2}{3-3};\ c\ \frac{1-1}{1-1};\ pm\ \frac{2-2}{2-2};\ m\ \frac{3-3}{3-3} = 34.$$

The lower incisors (fig. 548) are comb-like, having their crowns split into narrow strips. The outer upper incisors and the canines of both jaws have double roots. The præmolars and molars have cuspidate crowns.

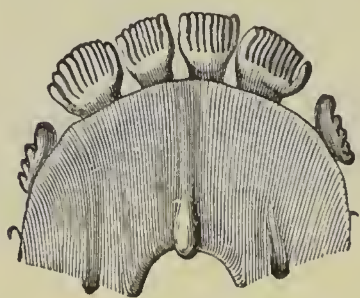

Fig. 548.—Front of the lower jaw of *Galeopithecus volans*, showing the form of the incisors. (After Owen.)

The *Galeopitheci* are not habitually insectivorous as regards their diet, but appear to live principally, if not exclusively, upon fruits and leaves. The stomach is of large size, and the intestine has a long cæcum. The Colugos are arboreal in their habits, and are principally active at night.

CHAPTER LXXV.

PRIMATES.

ORDER XVI. PRIMATES.—It is now very general to regard Man as being, zoologically, a member of a single order with the Monkeys, and this arrangement is an entirely defensible one so long as merely *anatomical* characters are taken as the basis of classification. The order *Primates*, therefore, in a narrower sense than that in which Linnæus understood the

term, may be substituted for the two orders of the *Quadrumana* and *Bimana*, which have been employed by Cuvier, Owen, and many other writers, for the reception of the Monkeys on the one hand, and of Man on the other hand.

The *Primates* may be defined by the possession of *perfect clavicles which articulate with the top of the sternum. The radius and ulna and tibia and fibula are complete, and are not anchylosed with one another.* (The tibia and fibula are conjoined inferiorly in *Tarsius*). *The hallux has a flat nail, and is commonly opposable to the other digits. The pollex is also usually opposable to the other digits of the manus. The typical dental formula is—*

$$i\,\frac{2-2}{2-2};\ c\,\frac{1-1}{1-1};\ pm\,\frac{2-2}{2-2}\text{ or }\frac{3-3}{3-3};\ m\,\frac{3-3}{3-3}=32\text{ or }36.$$

In no instance are there more than thirty-six teeth altogether, and the molars always have broad and tuberculate crowns. The mammary glands are typically two in number, and are almost always pectoral in position. The placenta is discoidal.

The order *Primates* may be considered under the three primary sections of (1) the *Lemuroidea*, embracing the Strepsirhine Monkeys or Lemurs, and their allies; (2) the *Simioidea*, including the Platyrhine and Catarhine Monkeys; and (3) Man.

I. Lemuroidea.

The Lemuroids, *Prosimii*, or *Strepsirhina*, are small arboreal animals, with the fore-limbs shorter than the hind-limbs, and the hallux opposable to the other digits, as also the pollex is as a rule. The second digit of the hind-foot has a curved claw, but in the typical Lemuroids all the other digits of both the pes and the manus have nails, those of the hallux and pollex being flat, while those of the other digits are more claw-like. The incisors (except in *Cheiromys*) are two in number on each side of each jaw, and the lower incisors are produced and slanting. The nostrils (fig. 549) are twisted and curved, with their convexities turned outwards, and placed at the end of the snout. It is upon this peculiarity in the shape of the nostrils that the name of *Strepsirhina*, applied to the group by Owen, was based. There may be two abdominal mammary glands (*Cheiromys*), or there may be abdominal mammæ in addition to the pectoral pair. None of the Lemuroids have a prehensile tail, cheek-pouches, or natal callosities.

About fifty species of Lemuroids are known, the majority

of which are peculiar to Madagascar. This is the case with all the true Lemurs, the Indrises, and the Aye-aye (*Cheiromys*). Many of the Galagos, the Potto, and the *Arctocebus* are natives

Fig. 549.—Head of *Indris Verreauxii*, showing the "Strepsirhine" type of nostrils. (After Grandidier.)

of the mainland of Africa. The "Slow Lemurs" (*Nycticebus*) are confined to the Oriental province, as are the Loris (Ceylon), and the Tarsier (Sumatra, Borneo, &c.). Speaking roughly, therefore, it may be said that the Lemuroids have Madagascar as their geographical centre, but that they spread westwards from this into Africa, and eastwards to India and the Indian Archipelago.

As regards their *distribution in time*, the Eocene deposits of both Europe and North America have yielded the remains of a number of small Mammals which have been referred to the Lemuroids. Some of these (such as *Necrolemur*) seem to be closely related to the recent Lemurs. Others, again, are of a generalised type, and show relationships to the Insectivores or to the Ungulates.

The *Lemuroidea* comprise the three families of the *Cheiromydæ*, *Tarsiidæ*, and *Lemuridæ*, of which the two first include each but a single genus and single species, while all the other forms of the group are contained in the third.

Fam. 1. *Cheiromydæ.*—This family is characterised by the non-opposable character of the pollex and the reduction of the incisors to one on each side of each jaw, and it includes only the extraordinary animal known as the Aye-aye (*Cheiromys madagascariensis*). The Aye-aye in appearance is not very unlike a large Squirrel, having a hairy body and a long

bushy tail. The dentition (fig. 550) is very like that of a Rodent, there being only a single incisor on each side of each jaw, and no canines, so that there is a wide gap between the

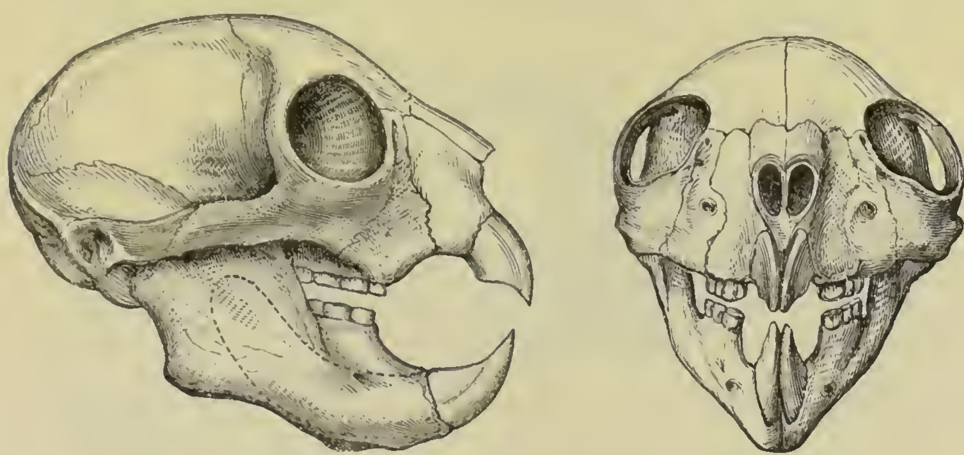

Fig. 550.—Skull of the Aye-aye (*Cheiromys*), viewed laterally and from the front. (After Owen.)

incisors and back teeth. Moreover, the incisors have chisel-shaped edges, and grow from permanent pulps; but the enamel covers their entire surface. The dental formula is—

$$i\ \frac{1-1}{1-1};\ c\ \frac{0-0}{0-0};\ pm\ \frac{1-1}{0-0};\ m\ \frac{3-3}{3-3} = 18.$$

The fore-feet have five toes, armed with strong claws, but the pollex is not opposable to the other digits. The middle finger is about as long as the ring-finger, but only about half as thick, its last two joints being hairless. The hind-feet have also five toes, of which the hallux is opposable, and the second digit is furnished with a long claw; as are all the toes except the hallux, which has a flat nail. The Aye-aye is confined to the forests of Madagascar.

Fam. 2. *Tarsiidæ.*—This family includes only the extraordinary little "Tarsier" (*Tarsius spectrum*) of Borneo, Sumatra, Celebes, and Banca, remarkable for the great length of the pes, due to the elongation of the tarsus, and particularly of the calcaneum. It is a little arboreal animal, about as big as a Squirrel, with enormously large eyes and a long tail. The two upper central incisors are larger than the lateral ones, and there is only a single incisor on each side in the lower jaw. The dental formula is—

$$i\ \frac{2-2}{1-1};\ c\ \frac{1-1}{1-1};\ pm\ \frac{3-3}{3-3};\ m\ \frac{3-3}{3-3} = 34.$$

Fam. 3. *Lemuridæ.*—The members of this family are characterised by the fact that the pollex, as well as the hallux, is opposable and furnished with a nail. There are two incisors on each side of each jaw, and the lower incisors are directed forwards (fig. 551).

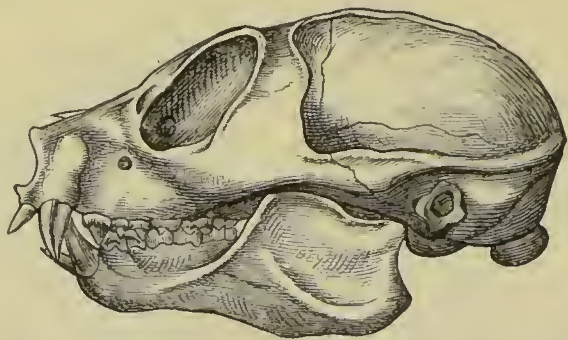

Fig. 551.—Side view of the skull of a Lemuroid (*Nycticebus*, or *Stenops*, *tardigradus*). (After Giebel.)

The typical forms of this family are the true Lemurs (*Lemurinæ*), in which the muzzle is elongated and pointed, and the nails on all the toes are flat, with the exception of the second toe of the hind-foot, which is furnished with a long and pointed claw. The body is covered with a woolly fur, and the tail is usually of considerable length, and is covered with hair. The dental formula in *Lemur* itself is—

$$i\,\frac{2-2}{2-2};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{3-3};\ m\,\frac{3-3}{3-3}=36.$$

The Lemurs are all natives of Madagascar, and are often domesticated. Well-known species are the Ring-tailed Lemur (*L. catta*) and the White-fronted Lemur (*L. albifrons*).

Allied to the preceding is a group of the *Lemuridæ* of which the genus *Indris* is the type (*Indrisinæ*). These have a shorter muzzle than the true Lemurs, and have only two præmolars on each side of each jaw. Well-known species are the Woolly Lemur (*Indris laniger*) and the Diadem Lemur (*I. diadema*). All the forms of this group are confined to Madagascar.

A third group of the *Lemuridæ* is that of the "Galagos," comprising the genera *Cheirogale* and *Galago.* These have the tarsus greatly elongated. The genus *Cheirogale* is confined to Madagascar, but the species of *Galago* are widely distributed over Africa, being most abundant in the western part of the continent, but ranging to Senegal and the southern borders of the Sahara. The Galagos are elegant little animals, with long bushy tails, large eyes, and large membranous ears. A well-known species is the Maholi Galago.

The remaining members of the *Lemuridæ* are grouped together to form a special sub-family (*Nycticebinæ*), to which the name of "Slow Lemurs" is often given on account of the slow movements of the animals composing it. In this group there is no tail, or but a rudimentary one; the limbs are nearly equal in size; the ears are short and rounded, and the eyes are large, and are placed close together. The species of this family are all of small size, and are exclusively confined to the eastern portion of the Old World, occurring in Java, Ceylon, the southern parts of Asia, and other

localities in the same geographical area. They are nocturnal in their habits, living mostly on trees, and feeding upon insects. The best-known species are the Slender Loris (*Loris*, or *Stenops*, *gracilis*) of Ceylon, and the *Nycticebus tardigradus* of the East Indies. Here also belongs the "Potto" (*Perodicticus*) of Sierra Leone, in which the index-finger is rudimentary, and the *Arctocebus* of Old Calabar, in which this digit is reduced to a tubercle, and the tail is rudimentary.

II. Simioidea.

In the section of the *Simioidea* or *Simiadæ* are included all the animals ordinarily known as Monkeys and Apes—the Platyrhine and Catarhine Monkeys of Owen. These are distinguished from the other members of the *Primates* by having the hallux much shorter than the other digits of the pes, and always opposable. There is an interval (*diastema*) between the upper canines and incisors and between the lower canines and the first præmolars, the largely developed canine teeth being thus enabled to pass each other when the mouth is closed. There is but a single pair of mammary glands, and these are pectoral in position. In many cases, the cheeks are dilated into "cheek-pouches," and there are often spaces of thickened and naked skin over the ischia ("natal callosities").

The *Simioidea* are divided into the three groups of the *Arctopithecini* (Marmosets), the *Platyrhina* (Spider-monkeys, Howling Monkeys, &c.), and the *Catarhina* (Macaques, Baboons, Apes, &c.), of which the first two groups are wholly Neotropical in their range, and the last is entirely confined to the warmer parts of the Old World, and, with the exception of one species of Macaque, is restricted to Africa and to Asia and its islands.

As regards their *distribution in time*, the earliest types appear in the Miocene Tertiary of Europe, some of these early forms belonging to types now extinct (*Dryopithecus* and *Pliopithecus*), while others have been referred to existing genera. All the early forms of the Monkeys from the European Tertiaries are, moreover, referable to the section of the *Catarhina*, which at the present day is confined to the limits of the eastern hemisphere.

A. Arctopithecini.—This group includes only the Marmosets and their allies (*Hapalidæ*), often placed in the next section of the Monkeys, as their nose is of the "platyrhine" type, having the nostrils simple and placed widely apart. The *Arctopithecini* have the tail long, hairy, and not prehensile; there are no cheek-pouches, nor natal callosities; the fore-

limbs are shorter than the hind-limbs; the pollex is not opposable; and all the digits are clawed, with the exception of the opposable hallux, which has a flat nail. The number of the teeth is the same as in the Catarhine Monkeys and in Man, but there is a præmolar more and a molar less on each side of each jaw. The molar teeth have pointed cusps. The dental formula is—

$$i\,\frac{2-2}{2-2};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{3-3};\ m\,\frac{2-2}{2-2}=32.$$

The *Hapalidæ* are all small Monkeys, mostly about as big as Squirrels, and they are exclusively South American, occurring especially in Brazil. The best-known species is the common Marmoset (*Hapale Jacchus*), but several species are domesticated and kept as pets. The genus *Midas* comprises small Monkeys which differ from the Marmosets chiefly as regards the inclination of the incisor teeth.

B. PLATYRHINA.—This section includes all the South American Monkeys with the exception of the *Hapalidæ*. The tail in the Platyrhine Monkeys is long and is commonly prehensile; there are no cheek-pouches nor natal callosities; the fore-limbs are mostly shorter than the hind-limbs; and the pollex is not opposable to the other digits. The nostrils are of the "platyrhine" type, being separated by a broad septum, and opening laterally. There are three molars on each side of each jaw, as in the Catarhine Monkeys and in Man, while there is a præmolar more on each side than in these. The dental formula is—

$$i\,\frac{2-2}{2-2};\ c\,\frac{1-1}{1-1};\ pm\,\frac{3-3}{3-3};\ m\,\frac{3-3}{3-3}=36.$$

The section of the *Platyrhina* includes the single family of the *Cebidæ*, all the members of which are confined to the Neotropical province, ranging "from the southern part of Mexico to about the parallel of 30° south latitude" (Wallace). They are arboreal in their habits, and live partly on fruits and partly upon insects.

The Spider-monkeys (*Ateles*), the Howling Monkeys (*Mycetes*), the "Sapajous" or "Capuchins" (*Cebus*), and the Squirrel-monkey (*Callithrix*), may serve as typical examples of this section of the *Primates*. In *Ateles* the tail is long, slender, and powerfully prehensile; and the limbs are very long and slender. The pollex is absent, or is quite rudimentary. In *Mycetes* there is a bony drum which is formed by a dilatation of the os hyoides and communicates with the larynx.

The voice is thus rendered extraordinarily resonant. The pollex is not opposable, but is placed on a line with the other fingers.

In the so-called "Sakis" (*Pitheciidæ*) the tail is sometimes long (*Pithecia*), sometimes short (*Brachyurus*), but is never prehensile, while the lower incisors are inclined forwards. The little "Night-apes" (*Nyctipithecus*) also have non-prehensile tails, but the lower incisors are vertical, and the eyes, in accordance with the nocturnal habits of the animal, are of immense size.

C. CATARHINA.—In the Old World Monkeys included in this group, the tail may be long, or short, or wanting, but is never prehensile. Cheek-pouches and natal callosities are often present. The pollex (wanting in *Colobus*) is opposable to the other digits. The nostrils are of the "catarhine" type, being oblique, separated by a narrow septum, and so directed as to look downwards. The number of præmolars and molars is the same as in man, and the dental formula is—

$$i\,\frac{2-2}{2-2};\; c\,\frac{1-1}{1-1};\; pm\,\frac{2-2}{2-2};\; m\,\frac{3-3}{3-3} = 32.$$

The incisors are more or less prominent, and the canines—especially in the males—are of proportionately large size. There is always a diastema or gap in front of the upper canines and behind the lower canines.

The facial portion of the skull is always more developed in proportion to the size of the brain-case proper than is the case in Man, this being

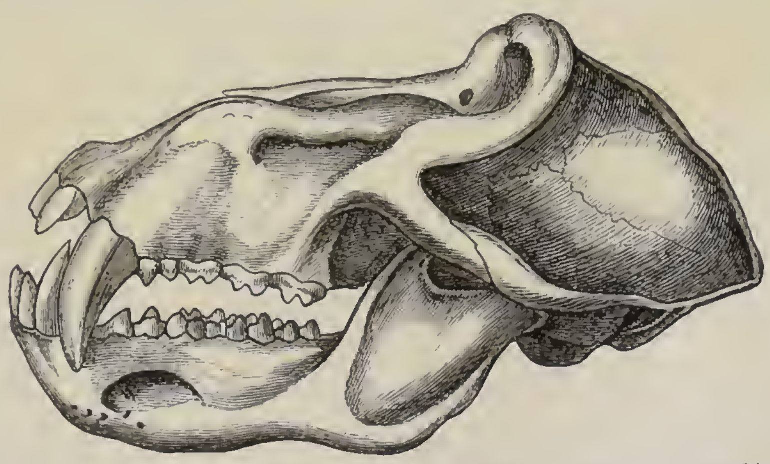

Fig. 552.—Side view of the skull of a Baboon (*Cynocephalus ursinus*). (After Giebel.)

most conspicuous in the Baboons (fig. 552), and least so in the Anthropomorphous Apes. The brain-case is of much the same form as in Man, and the cerebral fossa may or may not project backwards over the cere-

bellar fossa. The præmaxillæ remain as permanently distinct bones, the sutures between these and the maxillæ only becoming obliterated in aged specimens. The nasal bones often anchylose with one another in the middle line. There is a tubular meatus auditorius, and there is no tympanic bulla (a tympanic bulla is present in the *Platyrhina*). Except in one of the Gibbons (the Siamang), the mandible has no "chin," or "mental" protuberance. Lastly, the supraciliary ridges (fig. 552) are generally of great size.

The Catarhine Monkeys are essentially African and Asiatic, and are wholly confined to the Old World. A single species, the Barbary Ape (*Macacus inuus*), is found on the Rock of Gibraltar, and is the only Monkey which inhabits Europe. No Monkeys are found in Australia, but a species of Macaque inhabits the island of Timor, and thus belongs to the Australian province.

The Catarhine Monkeys are divided into the three families of the *Cynopithecidæ*, *Semnopithecidæ*, and *Anthropomorpha*.

Fam. I. *Cynopithecidæ.*—The Monkeys included in this family (Macaques, Guenons, Baboons, &c.) possess cheek-pouches and natal callosities. The condition of the tail is variable, being sometimes long, sometimes short, or wanting. The muzzle is usually prominent. The fore-limbs are longer than the hind-limbs, and the progression on the ground is quadrupedal, the animal applying the soles of the feet and the palms of the hands to the ground. The cæcum has no vermiform appendix, and the outer lower incisors are not larger than the central ones.

Some of the Monkeys included in this family are small, long-tailed, and comparatively graceful animals. This is the case with the little African Monkeys known as "Guenons," "Green Monkeys," &c. (*Cercopithecus*), and the "Mangabeys," (*Cercocebus*, fig. 553). Nearly related to the preceding are the "Macaques" (*Macacus*), which are found both in Africa and over the whole of Southern Asia and the Malay Archipelago, and in which the tail is often short or wanting. Well-known examples of these are the Rhesus Monkey (*M. rhesus*) of India, the Wanderoo (*M. silenus*) of Malabar, the common Macaque (*M. cynomolgus*) of Southern Asia and the Malay Archipelago, and the Barbary Ape (*M. inuus*) of North Africa and the Rock of Gibraltar.

A special group of the *Cynopithecidæ* is constituted by the Baboons (*Cynocephalus*), which are all inhabitants of Africa and Arabia. The Baboons are large, dog-faced Monkeys, with long muzzles and terminal nostrils. The fore and hind limbs are of nearly equal length, and, more than any others of the Monkeys, they employ the fore-limbs in terrestrial progression, running upon all-fours with the greatest ease. The supraciliary ridges of the skull are very pronounced (fig. 552), and the canines are of large size. The natal callosities are large and conspicuous, and commonly of some bright colour. Among the best known of the Baboons are the Mandrill (*Cynocephalus maimon*) and Drill (*C. leucophæus*) of Western Africa; the common Baboon (*C. papio*) of Eastern Africa; the Chacma or Pig-faced Baboon (*C. porcarius*) of South Africa; and the

Sacred Baboon or Gray Baboon (*C. hamadryas*) of Abyssinia and the western littoral of Arabia. Possibly allied to the Baboons is the genus *Cynopithecus*, the only known species of which is found in Celebes and the Philippine Islands.

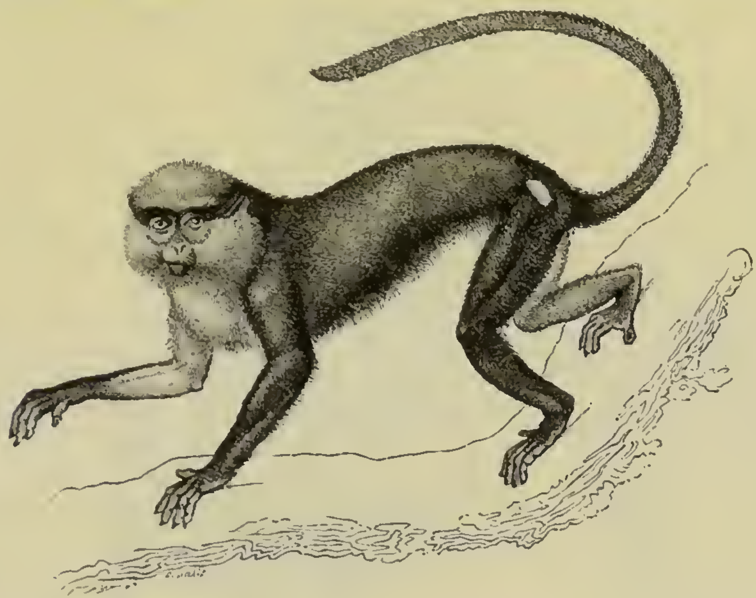

Fig. 553.—*Cercocebus mona*, one-seventh of the natural size.

Fam. 2. *Semnopithecidæ.*—This family comprises the *Semnopitheci* of the Oriental province and the *Colobi* of Africa, which have the tail long, and possess natal callosities, but which have no cheek-pouches. The fore-limbs are shorter than the hind-limbs, and progression on the ground is quadrupedal. The pollex is small, and may be wanting altogether. The cæcum is without a vermiform appendix, and the outer lower incisors are not larger than the central ones.

The genus *Semnopithecus* is wholly confined to Southern Asia and the Malay Archipelago, in which regions it is represented by a number of species. Well-known forms are the Entellus Monkey or Sacred Monkey of the Hindoos (*S. entellus*), and the Proboscis Monkey or Kahau (*S.* or *Presbytis, nasalis*) of Borneo, in which the nose is greatly prolonged. The genus *Colobus* is wholly African, and differs from *Semnopithecus* in the fact that the pollex is wanting.

Fam. 3. *Anthropomorpha.*—The Anthropomorphous, or Anthropoid, Apes included in this section are destitute of a tail and of cheek-pouches, while there are mostly no natal callosities. The fore-limbs are longer than the hind-limbs (fig. 554), and the animal can progress in a semi-erect position. The cæcum has a vermiform appendix, and the outer lower incisors are larger than the central ones, the reverse of

this obtaining in the upper jaw. The sternum is broad and flat, as it is in Man, and they are for this reason sometimes

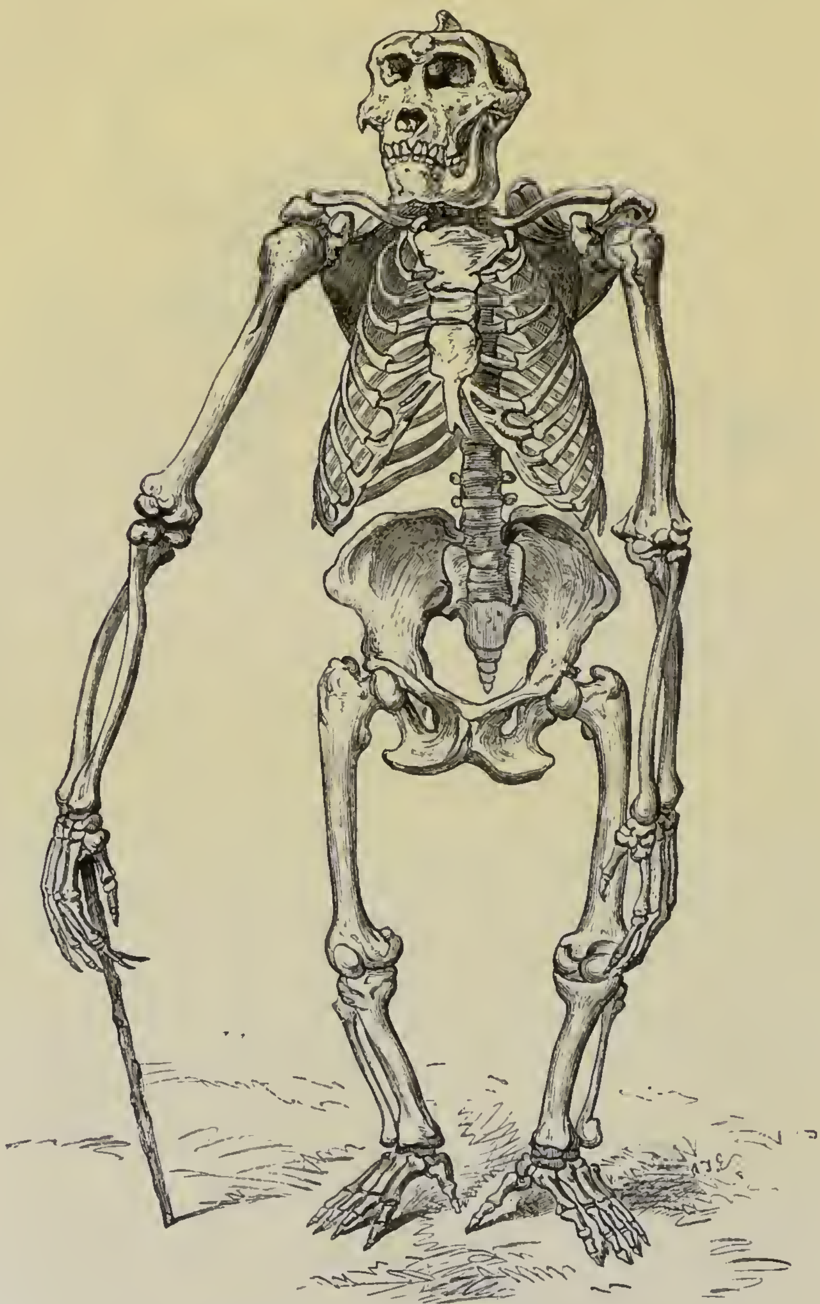

Fig. 554.—Skeleton of the Gorilla (*Troglodytes gorilla*).

spoken of as "Latisternal Apes." The pollex is never rudimentary, and is always opposable to the other digits. The

hallux is articulated at an angle to the other digits, and is opposable. The spine shows a single curve, and articulates with the back of the skull. The canines are of large size, especially in the males. The muzzle projects to a greater or less extent, and the muscular ridges of the skull are usually greatly developed.

This group of the *Catarhina* includes the Gibbons (*Hylobates*), the Orang-utan (*Simia* or *Pithecus*), and the Chimpanzee and Gorillas (*Troglodytes*), of which the two former are confined to the Oriental province, while the latter are exclusively African.

The Gibbons form the genus *Hylobates*, and inhabit South-eastern Asia and the Indian Archipelago. The arms are extremely long, and the hands reach to the ankles, or even to the ground, when the animal stands in an erect position. There is no tail, but small natal callosities are present. The body is covered with a thick fur. The sternum is wider than in the other Apes, and in one species (the Siamang) there is a distinct chin. The largest of the Gibbons is the Siamang (*H. syndactylus*), which inhabits the Malay Peninsula and Sumatra. It derives its specific name from the fact that the index and middle toes are united by the skin to the last joint. Other well-known species are the White-handed Gibbon (*H. lar*) and the Silvery Gibbon (*H. leuciscus*).

In the Orang or "Mias" (*Simia satyrus*) there are neither cheek-pouches nor natal callosities, and the hips are covered with hair. As in the Gibbons, the arms are excessively long, reaching considerably below the knee when the animal stands in an erect posture. The hind-legs are very short, and there is no tail. When full grown, the Orang stands about four feet high. It never progresses with the help of a stick, or walks erect at all, except along the branches of trees, supporting itself by a higher branch, or when attacked. When young, the head of the Orang is not very different from that of an average European child; but, as the animal grows, the facial bones become gradually produced, whilst the cranium remains in a tolerably stationary condition; great bony ridges are developed for the attachment of the muscles of the jaws and face; the incisors project; and ultimately the muzzle becomes as pronounced and well-marked a feature as in many of the *Carnivora* (fig. 555, A). The Orangs are inhabitants of Sumatra and Borneo. They are arboreal in their habits, and form for themselves a sort of nest or shelter amongst the trees. The forehead is rounded, the cerebrum is greatly convoluted, and the canine teeth of the full-grown males are very large.

The genus *Troglodytes* contains the Chimpanzee (*T. niger*) and the Gorilla (*T. gorilla*), with some less perfectly known forms. The Chimpanzee is a native of Western Africa, extending its range eastwards to Abyssinia. It has the arms much shorter, proportionately, than in the Gibbons and Orangs; still they are much longer than the hind-limbs, and they reach beneath the knee when the animal stands erect. The ears in the Chimpanzee are large, and the body is covered with dark-brown hair. The animal can stand erect, but the natural mode of progression is on all-fours. The hands are naked to the wrist, and the face is also naked, and is much wrinkled. The Chimpanzee lives in society in wooded districts, constructs a kind of nest, and can effectually defend itself against even the largest of its foes.

The Gorilla (*Troglodytes gorilla*) is much larger than the Chimpanzee, a full-grown male being over five feet and a half in height. The muzzle is prominent; the supraciliary ridges and sagittal crest of the skull are enor-

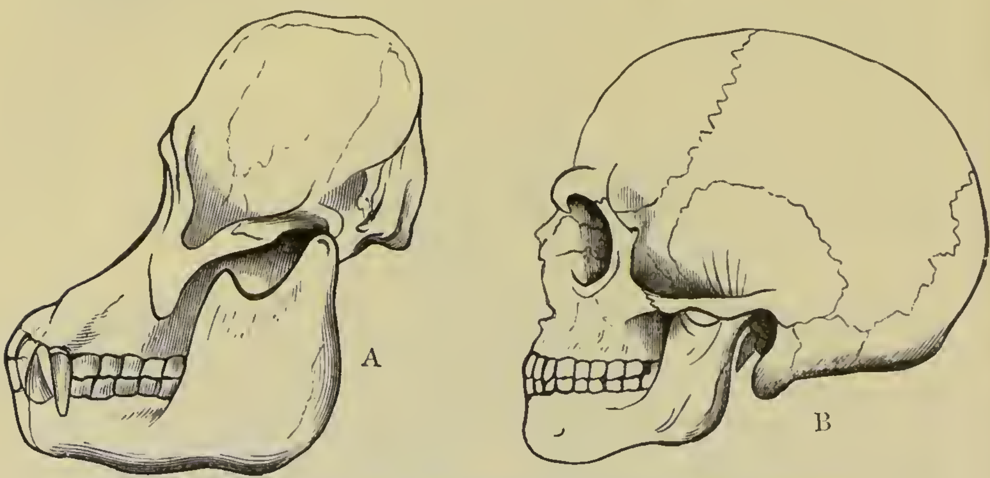

Fig. 555.—A, Skull of the Orang-utan. B, Skull of an adult European.

mously developed in the old animal (fig. 554); and the canines are of great size. The fore-limbs are long, and extend about to the knees when the animal stands erect. The palms and soles of the feet are naked and hairless, black in colour, the fingers rendered in appearance shorter than they really are by the extension forwards of the integument between them. The cranial capacity is about thirty-one cubic inches, that of the average European being about ninety-three cubic inches, and that of the average Australian seventy-five cubic inches. The Gorilla is essentially arboreal in its habits; and the male builds a sort of nest in a tree, in which the female brings forth its young. The Gorilla is an inhabitant of equatorial Africa, and is an enormously strong and ferocious animal.

Another species of the genus *Troglodytes* is the Bald-headed Chimpanzee (*T. calvus*), which is likewise found in Western Africa, and another has been described under the name of *T. Aubryi*.

Man.

Man (*Homo*) is distinguished from the other *Primates* by his habitually erect posture and bipedal progression. The lower limbs are exclusively devoted to progression and to supporting the weight of the body, the foot being broad and plantigrade, with a well-developed "heel." The hallux is shorter than the second digit, with which it is placed in a line, and it is not opposable. The fore-limb is shorter than the hind-limb, and has nothing to do with progression, but subserves prehension. The pollex is articulated at an angle with the other digits, and is not only opposable, but is capable of adduction and abduction. The spine has a double curve.

The skull has the occipital condyles placed within its middle fifth, in adaptation to the vertical position of the spine. There is no sagittal crest, and the supraciliary ridges are little developed. The symphysis of the mandible has a well-marked "mental" protuberance. The sutures between the præmaxillæ and maxillary bones are, normally, altogether obliterated.

The dentition consists of thirty-two teeth, which form a nearly even and uninterrupted series, without any diastema or interval. The canines are not markedly larger than the incisors. The dental formula is—

$$i\,\frac{2-2}{2-2};\ c\,\frac{1-1}{1-1};\ pm\,\frac{2-2}{2-2};\ m\,\frac{3-3}{3-3}=32.$$

The capacity of the brain-case varies from about fifty to over a hundred cubic inches, and is never less than forty cubic inches. The brain averages from forty-five to sixty ounces in weight, the cerebral lobes being proportionately larger, and its surface being more abundantly and deeply convoluted than is the case with any other Mammal.

The development of hair is, lastly, but partial, and Man is the only terrestrial Mammal in which the body is not provided, at any rate on the dorsal surface, with a covering of hair.

By Cuvier, Owen, and many other naturalists, Man has been regarded as constituting by himself a distinct order of Mammals, to which the name of *Bimana* has been given. At the present day, on the other hand, it is usual to regard Man, from a purely zoological point of view, as constituting a special section (*Anthropidæ*) of the order *Primates*.

With regard to the distribution of Man in *time*, our knowledge is at present doubtless very defective. So far as is certainly known, no remains of Man, in the form of bones or of implements, have as yet been detected in deposits of greater age than the Pleistocene period. It is, however, certain that Man existed in Western Europe in the later half of the Pleistocene (Post-pliocene) period, along with a large number of Mammals which are now extinct.

LITERATURE.

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GLOSSARY.

ABACTINAL (Lat. *ab*, away from; Gr. *aktin* or *aktis*, a ray). Applied to the side of an Echinoderm opposite to that on which the mouth is situated.

ABDOMEN (Lat. *abdo*, I conceal; or contracted from *adipomen*, derived from *adeps*, fat). The hinder portion of the body-cavity of the higher animals, containing the principal digestive and excretory organs.

ABERRANT (Lat. *aberro*, I wander away). Departing from the regular type.

ABIOGENESIS (Gr. *a*, without; *bios*, life; *genesis*, origin). Spontaneous generation, or the production of living beings without pre-existent life.

ABNORMAL (Lat. *ab*, from; *norma*, a rule). Irregular; deviating from the ordinary standard.

ABOMASUM. The fourth cavity of the complex stomach of the Ruminants.

ABORAL (Lat. *ab*, away from; *os*, mouth). Applied to the side of the body opposite to that on which the mouth is situated.

ABRANCHIATE (Gr. *a*, without; *bragchia*, gills). Destitute of gills or branchiæ.

ACALEPHÆ (Gr. *akalephê*, a nettle). Applied formerly to the Jelly-fishes or Sea-nettles, and other Radiate animals, in consequence of their power of stinging, derived from the presence of microscopic cells, called "thread-cells," in the integument.

ACANTHOCEPHALA (Gr. *akantha*, a thorn; *kephalê*, head). An order of Scolecids, in which the head is armed with spines.

ACANTHOMETRINA (Gr. *akantha*; and *metra*, the womb). A family of *Radiolaria*, characterised by having radiating siliceous spines.

ACANTHOPTERYGII (Gr. *akantha*, spine; *pterux*, wing). A group of Bony fishes with spinous rays in the front part of the dorsal fin.

ACARINA (Gr. *akari*, a mite). A division of the *Arachnida*, of which the Cheese-mite is the type.

ACEPHALOUS (Gr. *a*, without; *kephalê*, head). Not possessing a distinct head.

ACETABULA (Lat. *acetabulum*, a cup). The suckers with which the cephalic processes of many *Cephalopoda* (Cuttle-fishes) are provided.

ACETABULUM. The cup-shaped socket of the hip-joint in Vertebrata.

ACONTIA (Gr. *akontion*, a javelin). Long filaments, charged with thread-cells, attached to the free edges of the mesenteries of Sea-anemones.

ACRANIATA (Gr. *a*, without; *kranion*, skull). A division of Vertebrates distinguished by the absence of a cranium, and comprising only the Lancelet.

ACRASPEDOTE (Gr. *a*, without; *kraspedon*, a fringe). Applied to Jelly-fishes (*Discophora*) in which the mouth of the swimming-bell is not restricted by a shelf-like "velum."

ACCRETION (Lat. *accresco*, I grow larger). The process by which inorganic bodies (such as crystals) grow larger, by the addition of fresh particles from the outside.

Acrita (Gr. *akritos*, confused). A term sometimes employed as synonymous with *Protozoa*, or the lowest division of the animal kingdom.

Acrodont (Gr. *akros*, high; *odous*, tooth). Having the teeth anchylosed with the summit of the alveolar border of the jaw.

Actinal (Gr. *aktin* or *aktis*, a ray). Applied to the side of the body of an Echinoderm on which the mouth is situated.

Actinomeres (Gr. *aktin*, a ray; *meros*, a part). The lobes which are mapped out on the surface of the body of the *Ctenophora*, by the ctenophores, or comb-like rows of cilia.

Actinosoma (Gr. *aktin;* and *soma*, body). Employed to designate the entire body of any *Actinozoön*, whether this be simple (as in the Sea-anemones), or composed of several zoöids (as in most Corals).

Actinotrocha (Gr. *aktin; trochos*, wheel). A peculiar type of larva seen in some Invertebrates (*Phoronis*, &c.) in which there is a ring of cilia at each end of the body and a circlet of tentacles.

Actinozoa (Gr. *aktin;* and *zoön*, an animal). That division of the *Cœlenterata* of which the Sea-anemones may be taken as the type.

Aculeus (Lat. a spine or sting). The "sting" of certain of the *Hymenoptera* (Bees, &c.)

Adductor (Lat. *adduco*, I bring together). The muscles which bring together the valves of the shell of the Bivalve Molluscs are known as the "adductors."

Adelarthrosomata (Gr. *adēlos*, hidden; *arthros*, joint; *soma*, body). An order of the *Arachnida*.

Æstivation (Lat. *æstivus*, relating to summer). The summer torpor exhibited by some animals during the hot season in warm countries.

Agamic (Gr. *a*, without; *gamos*, marriage). Applied to all forms of reproduction in which the sexes are not directly concerned.

Agamogenesis. Any form of non-sexual reproduction.

Allantoidea. The group of *Vertebrata* in which the fœtus is furnished with an allantois, comprising the Reptiles, Birds, and Mammals.

Allantois (Gr. *allas*, a sausage). One of the "membranes" of the fœtus in certain Vertebrates.

Alternation of Generations. The existence of a species in two different conditions, the one condition sexless, the other provided with reproductive organs, and each in turn producing the other.

Alveoli (Lat. dim. of *alvus*, belly). Applied to the sockets of the teeth.

Ambulacra (Lat. *ambulacrum*, a place for walking). The perforated spaces or "avenues" through which are protruded the tube-feet, by means of which locomotion is effected in the *Echinodermata*.

Ambulatory (Lat. *ambulo*, I walk). Formed for walking. Applied to a single limb or to an entire animal.

Ametabolic (Gr. *a*, without; *metabolê*, change). Applied to those insects which do not possess wings when perfect, and which do not, therefore, pass through any marked metamorphosis.

Amnion (Gr. *amnos*, a lamb). One of the fœtal membranes of the higher Vertebrates.

Amniota. The group of *Vertebrata* in which the fœtus is furnished with an amnion, comprising the Reptiles, Birds, and Mammals.

Amœba (Gr. *amoibos*, changing). A species of Rhizopod, so called from the numerous changes of form which it undergoes.

Amœbiform. Resembling an *Amœba* in form.

Amorphous (Gr. *a*, without; *morphê*, shape). Not having any definite figure.

Amorphozoa (Gr. *a*, without; *morphê*, shape; *zoön*, animal). A name sometimes used to designate the *Sponges*.

Amphibia (Gr. *amphi*, both; *bios*, life). A class of the *Vertebrata* comprising Frogs, Newts, and the like, which have always gills when young, but always develop lungs when fully grown. Most of them, therefore, live indifferently on land or in water.

Amphicœlous (Gr. *amphi*, at both ends; *koilos*, hollow). Applied to vertebræ which are concave at both ends.

AMPHIDISCS (Gr. *amphi*, at both ends; *diskos*, a quoit or round plate). The spicula which surround the gemmules of *Spongilla*, and resemble two toothed wheels united by an axle.

AMPHIOXUS (Gr. *amphi*, at both ends; *oxus*, sharp). The Lancelet, a little fish, which alone constitutes the order *Pharyngobranchii*.

AMPHIPNEUSTA (Gr. *amphi*, both; *pneo*, I breathe). Applied to the "perennibranchiate" Amphibians, which retain their gills through life.

AMPHIPODA (Gr. *amphi*; and *pous*, a foot). An order of *Crustacea*.

AMPULLÆ (Lat. *ampulla*, a flask). In the Echinoderms the ampullæ are the little reservoirs attached to the bases of the tube-feet, and serving to fill these with fluid.

ANAL (Lat. *anus*, the vent). Connected with the anus, or situated near the anus.

ANALLANTOIDEA. The group of *Vertebrata* in which the embryo is not furnished with an allantois.

ANALOGOUS. Applied to parts which perform the same function.

ANAMNIOTA. The group of *Vertebrata* in which the embryo is destitute of an amnion.

ANARTHROPODA (Gr. *a*, without; *arthros*, a joint; *pous*, foot). That division of *Annulose* animals in which there are no articulated appendages.

ANCHYLOSIS or ANKYLOSIS (Gr. *ankulos*, crooked). The union of two bones by osseous matter, so that they become one bone, or are immovably joined together.

ANDROGYNOUS (Gr. *anēr*, a man; *gunē*, a woman). Synonymous with hermaphrodite, and implying that the two sexes are united in the same individual.

ANDROPHORES (Gr. *anēr*, a man; *phero*, I carry). Applied to medusiform gonophores of the *Hydrozoa*, which carry the spermatozoa, and differ in form from those in which the ova are developed.

ANNELIDA (a Gallicised form of *Annulata*). The Ringed Worms, which form one of the divisions of the *Anarthropoda*.

ANNULATED. Composed of a succession of rings.

ANNULOSA (Lat. *annulus*, a ring). The sub-kingdom comprising the Scolecids, the Worms, and the Articulate animals.

ANOMODONTIA (Gr. *anomos*, irregular; *odous*, tooth). An extinct order of Reptiles, often called *Dicynodontia*.

ANOMURA (Gr. *anomos*, irregular; *oura*, tail). A tribe of Decapod *Crustacea*, of which the Hermit-crab is the type.

ANOPLURA (Gr. *anoplos*, unarmed; *oura*, tail). An order of Apterous Insects.

ANOURA or ANURA (Gr. *a*, without; *oura*, tail). The order of *Amphibia* comprising the Frogs and Toads, in which the adult is destitute of a tail. Often called *Batrachia*.

ANTENNÆ (Lat. *antenna*, a yard-arm). The jointed horns or feelers possessed by the majority of the *Articulata*.

ANTENNULES (dim. of *antennæ*). Applied to the smaller pair of antennæ in the *Crustacea*.

ANTHROPOID (Gr. *anthrōpos*, man; *eidos*, form). Resembling man.

ANTHROPOMORPHOUS (Gr. *anthrōpos*, man; *morphē*, shape). Resembling man in form.

ANTIBRACHIUM (Gr. *anti*, in front of; *brachion*, the arm). The fore-arm of the higher Vertebrates, composed of the *radius* and *ulna*.

ANTLERS. Properly the branches of the horns of the Deer tribe (*Cervidæ*), but generally applied to the entire horns.

ANTLIA (Lat. *antlia*, a pump). The spiral trunk or proboscis with which Butterflies and other Lepidopterous Insects suck up the juices of flowers.

APHANIPTERA (Gr. *aphanos*, inconspicuous; *pteron*, a wing). An order of Insects comprising the Fleas.

APLACENTALIA. The section of the *Mammalia*, comprising the two divisions of the *Didelphia* and *Monodelphia*, in which the young is not furnished with a placenta.

APODA (Gr. *a*, without; *podes*, feet). Applied to those fishes which have no

ventral fins. Also to the footless *Cæciliæ* amongst the *Amphibia*. Also to those Holothurians which have no tube-feet.

APODAL. Devoid of feet.

APODEMATA (Gr. *apodaio*, I portion off). Applied to chitinous septa which divide the tissues in *Crustacea*, and to which muscles are attached.

APROCTOUS (Gr. *a*, without; *prōktos*, the anus). Not having an anal opening.

APTERA (Gr. *a*, without; *pteron*, a wing). A division of Insects, which is characterised by the absence of wings in the adult condition.

APTEROUS. Devoid of wings.

APTERYX (Gr. *a*, without; *pterux*, wing). A genus of Ratite Birds.

AQUIFEROUS (Lat. *aqua*, water; *fero*, I carry). Water-bearing: applied to all vessels or canals by which water is distributed through an organism.

ARACHNIDA (Gr. *arachnē*, a spider). A class of the *Articulata*, comprising Spiders, Scorpions, and allied animals.

ARANEIDA (Lat. *aranea*, a spider). The order of *Arachnida*, comprising the true Spiders.

ARBORESCENT. Branched like a tree.

ARCHÆOPTERYX (Gr. *archaios*, ancient; *pterux*, wing). The singular fossil bird which alone constitutes the order of the *Saururæ*.

ARCHENCEPHALA (Gr. *archo*, I overrule; *egkephalos*, brain). The name applied by Owen to his fourth and highest group of *Mammalia*, comprising Man alone.

ARENACEOUS. Sandy, or composed of grains of sand.

ARTHROPODA (Gr. *arthros*, joint; *podes*, feet). The division of *Annulosa*, comprising the Crustaceans, Myriopods, Arachnids, and Insects, in all of which jointed or articulated limbs are normally present.

ARTICULATA (Lat. *articulus*, a joint). The *Arthropoda* are often spoken of as *Articulata* or "Articulate animals."

ARTIODACTYLA (Gr. *artios*, even; *daktulos*, a finger or toe). A division of the hoofed quadrupeds (*Ungulata*) in which each foot has an even number of toes (two or four).

ASCIDIOIDA (Gr. *askos*, a wine-skin or bottle; *eidos*, form). A name sometimes given to the Tunicates, the simple forms of which have the shape of a two-necked bottle.

ASEXUAL. Applied to modes of reproduction in which the sexes are not concerned.

ASIPHONATE. Not possessing a respiratory tube or siphon. Applied to a division of the *Lamellibranchiate* Molluscs.

ASTEROID (Gr. *aster*, a star; and *eidos*, form). Star-shaped, or possessing radiating lobes or rays like a Star-fish.

ASTEROIDEA. An order of *Echinodermata*, comprising the Star-fishes, characterised by their rayed form.

ASTOMATOUS (Gr. *a*, without; *stoma*, mouth). Not possessing a mouth.

ATLAS (Gr. the god who holds up the earth). The first vertebra of the neck, which articulates with and supports the skull.

ATRIUM (Lat. a hall). Applied to the great chamber or "cloaca," into which the intestine opens in the *Tunicata*. Also applied to the auricular division of the heart.

AURELIA (Lat. *aurum*, gold). Applied to the chrysalides of some *Lepidoptera*, on account of their exhibiting a golden lustre.

AURICLE (Lat. dim. of *auris*, ear). Applied to one of the cavities of the heart, by which blood is driven into the ventricle.

AURICULARIA. The barrel-shaped larva of the Holothurians, in which the body is furnished with transverse belts of cilia.

AUTOPHAGI (Gr. *autos*, self; *phago*, I eat). Applied to birds whose young can run about and obtain food for themselves as soon as they escape from the egg.

AVES (Lat. *avis*, a bird). The class of the Birds.

AVICULARIUM (Lat. *avicula*, dim. of *avis*, a bird). A modified zoöid, often shaped like the head of a bird, found in many of the *Polyzoa*.

AXIS (Gr. *axōn*, a pivot). The second vertebra of the neck, upon which the skull and atlas usually rotate.
AZYGOUS (Gr. *a*, without; *zugon*, yoke). Single; without a fellow.

BACTERIUM (Gr. *bakterion*, a staff). A microscopic organism occurring in fluids containing organic matter, and having a staff-shaped form.
BALANCERS. The knobbed filaments which represent the hinder pair of wings in Dipterous insects.
BALANIDÆ (Gr. *balanos*, an acorn). A family of sessile *Cirripedes*, commonly called "Acorn shells."
BALEEN (Lat. *balæna*, a whale). The horny plates which occupy the palate of the "whalebone" Whales.
BATIDES (Gr. *batos*, a bramble). The family of the *Elasmobranchii* comprising the Rays.
BATRACHIA (Gr. *batrachos*, a frog). Often loosely applied to any of the *Amphibia*, but sometimes restricted to the Amphibians as a class, or to the single order of the *Anoura*.
BELEMNITIDÆ (Gr. *belemnon*, a dart). An extinct group of Dibranchiate Cephalopods, comprising the Belemnites and their allies.
BICAVITARY (Lat. *bis*, twice; *cavus*, hollow). Consisting of, or possessing, two cavities.
BIFID. Cleft into two parts; forked.
BILATERAL. Having two symmetrical sides.
BIMANA (Lat. *bis*, twice; *manus*, hand). Applied as an ordinal name to Man, in contradistinction to the other *Primates* (*Quadrumana*).
BIPEDAL (Lat. *bis*, twice; *pes*, foot). Walking upon two legs.
BIPINNARIA (Lat. *bis*, twice; *pinna*, a feather). A form of larva in the Star-fishes which has ciliated side-lappets.
BIRAMOUS (Lat. *bis*, twice; *ramus*, a branch). Applied to a limb which is divided into two branches (*e.g.*, the limbs of Cirripedes).
BIVALVE (Lat. *bis*, twice; *valvæ*, folding-doors). Composed of two plates or valves; applied to the shell of the *Lamellibranchiata* and *Brachiopoda*, and to the carapace of certain *Crustacea*.
BLASTEMA (Gr. *blastēma*, a germ, or growing thing). A mass of living matter in an actively growing condition.
BLASTODERM (Gr. *blastos*, a bud; *derma*, skin). The region in the segmented ovum ("germinal area") which subsequently becomes converted into the embryo.
BLASTOIDEA (Gr. *blastos*, a bud; and *eidos*, form). An extinct order of *Echinodermata*, often called *Pentremites*.
BLASTOPORE. The primitive mouth-opening formed in a double-layered embryo ("gastrula") by the invagination of the wall.
BLASTOSPHERE. The form of segmented ovum in which the cells arrange themselves in such a way as to enclose a central space ("segmentation-cavity").
BLASTOSTYLE (Gr. *blastos*, a bud; and *stulos*, a column). Applied by Prof. Allman to certain columniform zoöids in the *Hydrozoa*, which are destined to bear generative buds.
BRACHIOLARIA (Gr. *brachion*, arm). A form of larva in the Star-fishes which is furnished with long, movable, arm-like processes.
BRACHIOPODA (Gr. *brachion*, arm; *podes*, feet). A class of Molluscoid animals ("Lamp-shells," &c.), in which the mouth is furnished with two spirally-coiled, cirrated processes or "arms."
BRACHIUM (Gr. *brachion*, arm). Applied to the upper arm of Vertebrates.
BRACHYURA (Gr. *brachus*, short; *oura*, tail). A tribe of the Decapod *Crustaceans*, with short tails (*i.e.*, the Crabs).
BRACTS. (*See* Hydrophyllia.)
BRADYPODIDÆ (Gr. *bradus*, slow; *podes*, feet). The family of *Edentata* comprising the Sloths.
BRANCHIA (Gr. *bragchia*, the gill of a fish). A respiratory organ adapted to breathe air dissolved in water.
BRANCHIATE. Possessing gills or branchiæ.

BRANCHIFERA (Gr. *bragchia*, gill; and *phero*, I carry). A division of *Gastropodous Molluscs*, in which the respiration is aquatic, and the respiratory organs are mostly in the form of distinct gills.

BRANCHIOGASTROPODA (= Branchifera).

BRANCHIOPODA (Gr. *bragchia;* and *pous*, foot). A legion of *Crustacea*, in which the gills are supported by the feet.

BRANCHIOSTEGAL (Gr. *bragchia*, gill; *stego*, I cover). Applied to a membrane and rays by which the gills are protected in many fishes.

BREVILINGUIA (Lat. *brevis*, short; *lingua*, tongue). A division of the *Lacertilia.*

BREVIPENNATÆ (Lat. *brevis*, short; *penna*, a wing). A group of the Natatorial Birds.

BRONCHI (Gr. *brogchos*, the windpipe). The branches of the windpipe (*trachea*), by which the air is conveyed to the vesicles of the lung.

BRONTOTHERIDÆ (Gr. *Brontes*, the name of a giant; *therion*, beast). An extinct order of Tertiary Mammals.

BRUTA (Lat. *brutus*, heavy, stupid). Often used to designate the Mammalian order of the *Edentata.*

BRYOZOA (Gr. *bruon*, moss; *zoön*, animal). A synonym of *Polyzoa*, a class of the *Molluscoida.*

BUCCAL (Lat. *bucca*, mouth or cheeks). Connected with the mouth.

BURSIFORM (Lat. *bursa*, a purse; *forma*, shape). Shaped like a purse; subspherical.

BYSSIFEROUS. Producing a byssus.

BYSSUS (Gr. *bussos*, flax). A term applied to the silky filaments by which the *Pinna*, the common Mussel, and certain other Bivalve *Mollusca*, attach themselves to foreign objects.

CADUCIBRANCHIATE (Lat. *caducus*, falling off; Gr. *bragchia*, gill). Applied to those Amphibians in which the gills fall off before maturity is reached.

CADUCOUS. Applied to parts which fall off or are shed during the life of the animal.

CÆCAL (Lat. *cæcus*, blind). Terminating blindly or in a closed extremity.

CÆCUM (Lat. *cæcus*). A tube which terminates blindly.

CÆSPITOSE (Lat. *cæspes*, a turf). Tufted.

CAINOZOIC. (*See* Kainozoic.)

CALCAR (Lat. a spur). Applied to the "spurs" of Rasorial Birds; and also to the rudiments of the hind-limbs in certain snakes.

CALCAREOUS (Lat. *calx*, lime). Composed of carbonate of lime.

CALICE. The little cup in which the gastric sac of the polype of a coralligenous Zoophyte (*Actinozoön*) is contained.

CALYCOPHORIDÆ (Gr. *kalux*, a cup; and *phero*, I carry). An order of the Oceanic *Hydrozoa*, so called from their possessing bell-shaped swimming organs (*nectocalyces*).

CALYPTOBLASTIC (Gr. *kaluptos*, covered; and *blastos*, a bud). Applied by Prof. Allman to those *Hydrozoa* in which the nutritive or generative buds are provided with an external protective receptacle.

CALYX (Lat. *calyx*, a cup). Applied to the cup-shaped body of *Vorticella* (*Protozoa*), or of a *Crinoid* (*Echinodermata*).

CAMPANULARIDA (Lat. *campanula*, a bell), A group of Hydroid Zoophytes.

CANINE (Lat. *canis*, a dog). The eye-tooth of Mammals, or the tooth which is placed at or close to the præmaxillary suture in the upper jaw, and the corresponding tooth in the lower jaw.

CAPITULUM (Lat. dim. of *caput*, head). Applied to the body of a Barnacle (*Lepadidæ*), from its being supported upon a stalk or peduncle.

CARAPACE. A protective shield. Applied to the upper shell of Crabs, Lobsters, and many other *Crustacea ;* also to the case with which certain of the *Infusoria* are provided. Also the upper half of the immovable case in which the body of a Chelonian is protected.

CARINATÆ (Lat. *carina*, a keel). The division of Birds in which the sternum is furnished with a median ridge or keel.

CARNIVORA (Lat. *caro*, flesh ; *voro*, I devour). An order of the *Mammalia*.
CARNIVOROUS (Lat. *caro*, flesh ; *voro*, I devour). Feeding upon flesh.
CARNOSE (Lat. *caro*). Fleshy.
CARPOPHAGA (Gr. *karpos*, fruit ; *phago*, I eat). A section of the *Marsupialia*.
CARPUS (Gr. *karpos*, the wrist). The small bones which intervene between the fore-arm and the metacarpus.
CATARHINA (Gr. *kata*, downwards ; *rhines*, nostrils). The Old World Monkeys, so called from the form of the nostrils.
CAUDAL (Lat. *cauda*, the tail). Belonging to the tail.
CAVICORNIA (Lat. *cavus*, hollow ; *cornu*, a horn). The "hollow-horned" Ruminants, in which the horn consists of a central bony "horn-core" surrounded by a horny sheath.
CELL. A mass of protoplasm surrounded by an external "wall," and containing a "nucleus" in its interior.
CENTRUM (Gr. *kentron*, the point round which a circle is described by a pair of compasses). The central portion or "body" of a vertebra.
CEPHALIC (Gr. *kephalé*, head). Belonging to the head.
CEPHALOBRANCHIATE (Gr. *kephalé ;* and *braychia*, gill). Carrying gills upon the head. Applied to a section of the *Annelida*, which, like the *Serpulæ*, have tufts of external gills placed upon the head.
CEPHALOPHORA (Gr. *kephalé ;* and *phero*, I carry). Used synonymously with *Encephala*, to designate those *Mollusca* which possess a distinct head.
CEPHALOPODA (Gr. *kephalé ;* and *podes*, feet). A class of the *Mollusca*, comprising the Cuttle-fishes and their allies, in which there is a series of arms ranged round the head.
CEPHALOTHORAX (Gr. *kephalé*, head ; *thorax*, chest). The anterior division of the body in many Crustaceans, and in the *Arachnida*, which is composed of the coalescent segments of the head and thorax.
CERCARIIFORM (Lat. *cercaria*, a tailed animalcule ; and *forma*, shape). *Cercaria* (Gr. *kerkos*, tail) is the name of a tadpole-shaped animalcule ; and the epithet "cercariiform" is applied to all organisms of a similar shape (*e.g.*, the larval Tunicates).
CERE. The naked space found at the base of the bill of some birds.
CERVICAL (Lat. *cervix*, neck). Connected with the region of the neck.
CESTOIDEA (Gr. *kestos*, a girdle). A name for the *Tæniada*, a class of intestinal worms with flat bodies like tape (hence the name Tape-worms).
CESTRAPHORI (Gr. *kestra*, a weapon ; *phero*, I carry). The group of *Elasmobranchii* represented at the present day by the Port Jackson Shark.
CETACEA (Gr. *kētos*, a whale). The order of Mammals comprising the Whales and Dolphins.
CHÆTOGNATHA (Gr. *chaité*, bristle ; *gnathos*, jaw). An order of the *Anarthropoda*, comprising only the oceanic genus *Sagitta*.
CHÆTOPHORA (Gr. *chaité ; phero*, I carry) or CHÆTOPODA. Applied as a common name to the Tubicolous and Errant Annelides, both of which have bristle-bearing foot-tubercles, together with the Earth-worms and their allies (*Oligochæta*), which have locomotive bristles.
CHEIROPTERA (Gr. *cheir*, hand ; *pteron*, a wing). The order of Mammals comprising the Bats.
CHELÆ (Gr. *chēlé*, a claw). The pincers or prehensile claws with which some of the limbs are terminated in certain Arthropods (Lobster, Crab, Scorpion, &c.)
CHELATE. Possessing chelæ ; applied to a limb.
CHELICERÆ (Gr. *chēlé*, a claw ; *keras*, a horn, or antenna). Applied generally to the first pair of cephalic appendages of the Scorpion, which have the form of chelæ and are supposed to represent the antennæ of the other Arthropods. Sometimes used in a wide sense for the first pair of cephalic appendages in the *Arachnida*, whatever their form may be.
CHELONIA (Gr. *cheloné*, a tortoise). The order of Reptiles comprising the Tortoises and Turtles.
CHEVRON-BONES (Fr. *chevron*, a rafter). V-shaped bones (hæmal arches),

placed below the caudal vertebræ and protecting the backward continuation of the aorta.

CHEVROTAINS (Fr. *chèvre*, a goat). The little Ruminants which form the group of the *Tragulidæ*.

CHILOGNATHA (Gr. *cheilos*, a lip; and *gnathos*, a jaw). An order of the *Myriopoda*.

CHILOPODA (Gr. *cheilos;* and *podes*, feet). An order of the *Myriopoda*.

CHITINE (Gr. *chiton*, a coat). The peculiar substance, nearly allied to horn, which forms the exoskeleton in many Invertebrate animals, especially in the *Arthropoda* (*Crustacea*, *Insecta*, &c.)

CHLOROPHYLL (Gr. *chloros*, green; and *phullon*, a leaf). The green colouring matter of plants.

CHORDATA (Lat. *chorda*, a string). Applied as a general name to the Vertebrates, from their possession of a notochord.

CHROMATOPHORES (Gr. *chroma*, complexion, or colour; and *phero*, I carry). Little sacs which contain pigment-granules, and are found in the integument of Cuttle-fishes and other animals.

CHRYSALIS (Gr. *chrusos*, gold). The motionless pupa of butterflies and moths, so called because sometimes exhibiting a golden lustre.

CHYLAQUEOUS FLUID. A fluid consisting partly of water derived from the exterior, and partly of the products of digestion (chyle), occupying the body-cavity or perivisceral space in many Invertebrates (*Annelids, Echinoderms*, &c.), and sometimes having a special canal-system for its conduction (chylaqueous canals).

CHYLE (Gr. *chulos*, juice). The milky fluid which is the result of the action of the various digestive fluids upon the food.

CHYLIFIC (Gr. *chulos*, juice [chyle]; and Lat. *facio*, I make). Producing chyle. Applied to one of the stomachs, when more than one is present. The word is of mongrel origin; and "chylopoictic" is more correct.

CHYME (Gr. *chumos*, juice). The acid pasty fluid produced by the action of the gastric juice upon the food.

CHYME-MASS. A term sometimes applied to the central, semi-fluid sarcode in the interior of an *Infusorian*.

CILIA (Lat. *cilium*, an eyelash). Microscopic, hair-like filaments, which have the power of lashing backwards and forwards, thus creating currents in the surrounding or contiguous fluid, or subserving locomotion in the animal which possesses them.

CILIOGRADA (Lat. *cilium;* and *gradior*, I walk). Synonymous with *Ctenophora*, an order of *Actinozoa*.

CINCLIDES (Gr. *kigklis*, a lattice). Special apertures in the column walls of some Sea-anemones (*Actinidæ*), which probably serve for the emission of the cord-like "craspeda."

CINGULUM (Lat. a girdle). Applied to any belt-like ridge. In a restricted sense, used instead of "clitellum" to indicate the thickened region of the body of an Earth-worm or Leech, which is connected with the reproductive act.

CIRRI (Lat. *cirrus*, a curl). Tendril-like appendages, such as the feet of Barnacles, and Acorn-shells (*Cirripedes*), the lateral processes on the arms of *Brachiopoda*, &c.

CIRRIFEROUS or CIRRIGEROUS. Carrying cirri.

CIRRIPEDIA, CIRRHIPEDIA, or CIRRHOPODA (Lat. *cirrus*, a curl; and *pes*, a foot). A division of *Crustacea* with curled jointed feet.

CIRROSTOMI (Lat. *cirrus*, a tendril; Gr. *stoma*, mouth). Sometimes used to designate the *Pharyngobranchii*.

CLADOCERA (Gr. *klados*, a branch; *keras*, a horn). An order of *Crustacea* with branched antennæ.

CLAVATE (Lat. *clavus*, a club). Club-shaped.

CLAVICLE (Lat. *clavicula*, a little key). The "collar-bone," forming one of the elements of the pectoral arch of Vertebrates.

CLITELLUM or CLITELLUS (Lat. *clitellæ*, a pack-saddle). A thickened region of the body of certain Annelides connected with the act of reproduction.

CLOACA (Lat. a sink). The cavity into which the intestine and the ducts of the generative glands, and, when present, of the urinary organs, open in common in some Invertebrates (*e.g.*, in Insects), and also in many Vertebrate animals.

CLYPEIFORM (Lat. *clypeus*, a shield; and *forma*, shape). Shield-shaped; applied, for example, to the carapace of the King-crab.

CNIDÆ (Gr. *knidê*, a nettle). The urticating cells or "thread-cells," whereby many *Cœlenterate* animals obtain their power of stinging.

COCCYGEAL. Connected with the coccyx.

COCCYX (Gr. *kokkux*, a cuckoo). The terminal portion of the spinal column in man, so called from its fancied resemblance to a cuckoo's beak.

COCOON (French, *cocon*, the cocoon of the silk-worm; connected with Fr. *coque*, shell, which is derived from the Lat. *concha*). The outer covering of silky hairs with which the pupa or chrysalis of many insects is protected. The chitinous capsules in which Leeches and Earth-worms deposit their eggs. The silken cases which Spiders weave for their eggs.

CODONOSTOMA (Gr. *kodon*, a bell; *stoma*, mouth). The aperture or mouth of the disc (nectocalyx) of a *Medusa*, or of the bell (gonocalyx) of a medusiform gonophore.

CŒLENTERATA (Gr. *koilos*, hollow; *enteron*, the bowel). The sub-kingdom which comprises the *Hydrozoa* and *Actinozoa*. Proposed by Frey and Leuckart in place of the old term *Radiata*, which included other animals as well.

CŒLOMA (Gr. *koilos*, hollow). The proper body-cavity of the higher animals.

CŒNENCHYMA (Gr. *koinos*, common; *enchuma*, tissue—literally, an infusion). The common calcareous tissue which unites together the various corallites of a compound corallum.

CŒNŒCIUM (Gr. *koinos*, common; *oikos*, house). The entire dermal system of any *Polyzoön*; employed in place of the terms polyzoary or polypidom.

CŒNOSARC (Gr. *koinos*, common; *sarx*, flesh). The common organised medium by which the separate zoöids of a compound Cœlenterate animal are connected together.

CŒNOSTEUM (Gr. *koinos*, common; *osteon*, bone). The skeleton produced by the Hydrocorallines and Stromatoporoids.

COLEOPTERA (Gr. *koleos*, a sheath; *pteron*, wing). The order of Insects (Beetles) in which the anterior pair of wings are hardened, and serve as protective cases for the posterior pair of membranous wings.

COLLEMBOLA (Gr. *kolla*, glue; *embolos*, a sharp beak or pointed projection). An order of Apterous insects furnished with an adhesive ventral process.

COLLOID (Gr. *kolla*, glue; *eidos*, form). Glue-like. The "colloids" are those substances which, like albumen, will not pass through the pores of an animal membrane, or do so with great difficulty.

COLLOZOA (Gr. *kolla*, glue; *zoa*, animals). A group of Radiolarians.

COLUBRINA (Lat. *coluber*, a snake). A division of the *Ophidia*.

COLUMBACEI (Lat. *columba*, a dove). The division of Birds comprising the Doves and Pigeons.

COLUMELLA (Lat. dim. of *columna*, a column). In Conchology, the central axis round which the whorls of a spiral univalve are wound. Amongst the *Actinozoa*, it is the central axis or pillar which is found in the centre of the visceral chamber of many corals. In the skull of the Lizards, it is the rod-like bone which runs from the parietal to the pterygoid.

COLUMN. Applied to the cylindrical body of a Sea-anemone (*Actinia*); also to the jointed stem or peduncle of the stalked *Crinoids*.

COMMENSAL (Lat. *cum*, with; *mensa*, table). Living at the same table with; a messmate: Applied to animals which live on or in other animals for part or the whole of their life, simply sharing the food of their host, without being parasitic on him.

COMMISSURAL (Lat. *committo*, I solder together). Connecting together; usually applied to the nerve-fibres which unite different ganglia.

CONCHA (Lat. a shell). The external ear, by which sounds are collected and transmitted to the internal ear.

CONCHIFERA (Lat. *concha*, a shell; *fero*, I carry). Shell-fish. Applied in a restricted sense to the Bivalve Molluscs, and used as a synonym for *Lamellibranchiata*.

CONDYLE (Gr. *kondulos*, a knuckle). The surface by which one bone articulates with another. Applied especially to the articular surface or surfaces by which the skull articulates with the vertebral column.

CONIROSTRAL (Lat. *conus*, a cone; *rostrum*, a beak). Applied to the conical beak of certain Perching Birds.

CONJUGATION. The coalescence of two separate masses of protoplasm, followed by subdivision and the production of germs.

COPEPODA (Gr. *kopê*, an oar; *podes*, feet). An order of *Crustacea*.

CORACOID (Gr. *korax*, a crow; *eidos*, form). A separate bone which enters into the composition of the pectoral arch in Birds, Reptiles, and Monotremes. In most Mammals it is a mere process of the scapula, having, in man, some resemblance in shape to the beak of a crow.

CORALLIGENOUS. Producing a corallum.

CORALLITE. The corallum secreted by an *Actinozoön* which consists of a single polype; or the portion of a composite corallum which belongs to, and is secreted by, an individual polype.

CORALLUM (from the Latin for red coral). The hard structures deposited in, or by, the tissues of an *Actinozoön*—commonly called a "coral."

CORIACEOUS (Lat. *corium*, hide). Leathery.

CORPUS CALLOSUM (Lat. the "firm body"). The great band of nervous matter which unites the two hemispheres of the cerebrum in the Mammals.

CORPUSCULATED (Lat. *corpusculum*, a little body or particle). Applied to fluids which, like the blood, contain floating solid particles or "corpuscles."

CORTICAL LAYER. The layer of consistent sarcode, which in the *Infusoria* encloses the endoplasm, and is surrounded by the cuticle. Sometimes called the "parenchyma of the body."

COSTÆ (Lat. *costa*, a rib). Amongst the *Corals* the "costæ" are vertical ridges which occur on the outer surface of the theca, and mark the position of the septa within.

COSTAL (Lat. *costa*, a rib). Connected with the ribs.

CRANIATA (Gr. *kranion*, skull). A name given to all the Vertebrates, with the exception of the Lancelet, from their possession of a cartilaginous or bony brain-case.

CRANIUM (Gr. *kranion*, the skull). The bony or cartilaginous case in which the brain is contained.

CRASPEDA (Gr. *kraspedon*, a margin or fringe). The convoluted cords formed by the thickening of the free margins of the mesenteries of a Sea-anemone.

CRASPEDOTE (Gr. *kraspedon*, a fringe). Applied to those Jelly-fishes (*Medusæ*) in which the mouth of the swimming-bell is furnished with a shelf-like "velum."

CREPUSCULAR (Lat. *crepusculum*, dusk). Applied to animals which are active in the dusk or twilight.

CRINOIDEA (Gr. *krinon*, a lily; *eidos*, form). An order of *Echinodermata* comprising forms which are usually stalked, and sometimes resemble lilies in shape.

CROCODILIA (Gr. *krokodeilos*, a crocodile). An order of Reptiles.

CROP. A partial dilatation of the gullet, technically called "ingluvies."

CRUSTACEA (Lat. *crusta*, a crust). A class of *Arthropoda*, comprising Crabs, Lobsters, &c., characterised by the possession of a hard shell, or crust, which is cast periodically.

CRYSTALLOIDS. Substances which have mostly the power of crystallisation, are readily soluble, and form solutions which pass easily through the pores of animal membranes.

CTENOCYST (Gr. *kteis*, a comb; *kustis*, a bag or cyst). The sense-organ (probably auditory) which occurs in the *Ctenophora*.

CTENOID (Gr. *kteis*, a comb; *eidos*, form). Applied to those scales of fishes, the hinder margins of which are fringed with spines or comb-like projections.

CTENOPHORA (Gr. *kteis*, a comb; and *phero*, I carry). An order of *Actinozoa*, comprising oceanic creatures, which swim by means of "ctenophores," or bands of cilia arranged in comb-like plates.

CURSORES (Lat. *curro*, I run). A name for the Ratite Birds, given to them from their being destitute of the power of flight, but formed for running vigorously.

CUSPIDATE. Furnished with small pointed eminences or "cusps."

CUTICLE (Lat. *cuticula*, dim. of *cutis*, skin). The pellicle which forms the outer layer of the body amongst the *Infusoria*. The outer layer of the integument generally.

CUTIS (Lat. skin). The inferior vascular layer of the integument, often called the *cutis vera*, the *corium*, or the *dermis*.

CYCLOID (Gr. *kuklos*, a circle; *eidos*, form). Applied to those scales of fishes which have a regularly circular or elliptical outline, with an even margin.

CYCLOSTOMI (Gr. *kuklos*; and *stoma*, mouth). Sometimes used to designate the Hag-fishes and Lampreys, forming the order *Marsipobranchii*.

CYST (Gr. *kustis*, a bladder or bag). A sac or vesicle.

CYSTICA. The embryonic forms (scolices) of certain intestinal worms (Tapeworms), which were described as a distinct order, until their true nature was discovered.

CYSTOIDEA (Gr. *kustis*, a bladder; and *eidos*, form). An extinct order of *Echinodermata*.

CYTODE (Gr. *kutos*, a vessel; *eidos*, form). A mass of protoplasm, which differs from a cell in the want of a definite "wall," and the absence of a "nucleus."

DECAPODA (Gr. *deka*, ten; *podes*, feet). The division of *Crustacea* which have ten ambulatory feet; also the family of Cuttle-fishes, in which there are ten arms or cephalic processes.

DECIDUOUS (Lat. *decido*, I fall off). Applied to parts which fall off or are shed during the life of the animal.

DECOLLATED (Lat. *decollo*, I behead). Applied to univalve shells, the apex of which falls off in the course of growth.

DEINOCERATA or DINOCERATA (Gr. *deinos*, terrible; *keras*, horn). An extinct order of Tertiary Mammals.

DEINOSAURIA or DINOSAURIA (Gr. *deinos*, terrible; *saura*, lizard). An extinct order of Reptiles.

DENDRIFORM, DENDRITIC, DENDROID (Gr. *dendron*, a tree). Branched like a tree, arborescent.

DENTIROSTRES (Lat. *dens*, a tooth; *rostrum*, a beak). The group of Perching Birds in which the upper mandible of the beak has its lower margin toothed.

DERMA or DERMIS. (See Cutis.)

DERMAL (Gr. *derma*, skin). Belonging to the lower layer of the integument.

DERMOSCLERITES (Gr. *derma*, skin; *skleros*, hard). Calcareous spicules which occur in the tissues of some of the *Alcyonaria* (*Actinozoa*).

DESMIDIÆ. Minute fresh-water plants, of a green colour, without a siliceous epidermis.

DEUTEROZOÖIDS (Gr. *deuteros*, second; *zoön*, animal; *eidos*, form). The zoöids which are produced by gemmation from zoöids.

DEXTRAL (Lat. *dextra*, the right hand). Right-handed; applied to the direction of the spiral in the greater number of univalve shells.

DIAPHRAGM (Gr. *diaphragma*, a partition). The "midriff," or the muscle which in *Mammalia* forms a partition between the cavities of the thorax and abdomen.

DIASTEMA (Gr. *dia*, apart; *histēmi*, I place). A gap or interval, especially between teeth.

DIASTOLÉ (Gr. *diastello*, I separate or expand). The expansion of a contractile cavity such as the heart, which follows its contraction or "systolé."

DIATOMACEÆ (Gr. *diatemno*, I sever). An order of minute plants, which are provided with siliceous envelopes.

DIBRANCHIATA (Gr. *dis*, twice; *bragchia*, gill). The order of *Cephalopoda* (comprising the Cuttle-fishes, &c.) in which only two gills are present.

DICYNODONTIA (Gr. *dis*, twice; *kuon*, dog; *odous*, tooth). An extinct order of Reptiles.
DIDELPHIA (Gr. *dis*, twice; *delphus*, womb). The subdivision of Mammals comprising the Marsupials.
DIGIT (Lat. *digitus*, a finger). A finger or toe.
DIGITIGRADA (Lat. *digitus; gradior*, I walk). A subdivision of the *Carnivora*.
DIGITIGRADE. Walking upon the tips of the toes, and not upon the soles of the feet.
DIMEROSOMATA (Gr. *dis; meros*, part; *soma*, body). An order of *Arachnida*, comprising the true Spiders, so called from the marked division of the body into two regions, the cephalothorax and abdomen. The name *Araneida* is often employed for the order.
DIMYARY (Gr. *dis*, twice; *muon*, muscle). Applied to those Bivalve Molluscs (*Lamellibranchiata*) in which the shell is closed by two adductor muscles.
DIŒCIOUS (Gr. *dis*, twice; *oikos*, house). Having the sexes distinct; applied to species which consist of male and female individuals.
DIPHYCERCAL (Gr. *dis*, twice; *phuo*, I generate; *kerkos*, tail). Applied to the tail of Fishes when the extremity of the notochord divides the fin-rays into two equal moieties.
DIPHYODONT (Gr. *dis*, twice; *phuo*, I generate; *odous*, tooth). Applied to those Mammals which have two sets of teeth.
DIPHYOZOÖIDS. Detached reproductive portions of adult *Calycophoridæ*, an order of oceanic *Hydrozoa*.
DIPNOI (Gr. *dis*, twice; *pnoé*, breath). The order of fishes represented by the *Lepidosiren*.
DIPTERA (Gr. *dis*, twice; *pteron*, wing). An order of insects characterised by the possession of two wings.
DISCOID (Gr. *diskos*, a quoit; *eidos*, form). Shaped like a round plate or quoit.
DISCOPHORA (Gr. *diskos*, a quoit; *phero*, I carry). This term is applied to the Sea-blubbers (Acraspedote Jelly-fishes) from their form; and is sometimes used to designate the order of the Leeches (*Hirudinea*) from the suctorial discs which these animals possess.
DISSEPIMENTS (Lat. *dissepio*, I partition off). Partitions. Used in a restricted sense to designate certain imperfect transverse partitions, which grow from the septa of many corals.
DISTAL. Applied to the quickly growing end of the hydrosoma of a *Hydrozoön;* the opposite, or "proximal" extremity growing less rapidly, and being the end by which the organism is fixed, when attached at all. Applied in general to the end of an appendage, limb, bone, &c., which is furthest removed from the trunk.
DIURNAL (Lat. *dies*, day). Applied to animals which are active during the day.
DIVERTICULUM (Lat. *diverticulum*, a by-road). A lateral tube with a blind extremity springing from the side of another tube.
DORSAL (Lat. *dorsum*, back). Connected with the back.
DORSIBRANCHIATE (Lat. *dorsum*, the back; Gr. *bragchia*, gill). Having external gills attached to the back; applied to certain *Annelides* and *Molluscs*. The term is of mongrel composition, and "notobranchiate" is more correctly employed.

ECDERON (Gr. *ek*, out; *deros*, skin). The outer plane of growth of the external integumentary layer (viz., the ectoderm, or epidermis).
ECDYSIS (Gr. *ekdusis*, a stripping off). A shedding or moulting of the skin.
ECHINOCOCCI (Gr. *echinos*, a hedgehog; *kokkos*, a berry). The larval forms (scolices) of one of the tape-worms of the dog (*Tænia echinococcus*), commonly known as "hydatids."
ECHINODERMATA (Gr. *echinos;* and *derma*, skin). A class of animals comprising the Sea-urchins, Star-fishes, and others, most of which have spiny skins.
ECHINOIDEA (Gr. *echinos;* and *eidos*, form). An order of *Echinodermata*, comprising the Sea-urchins.
ECHINOPÆDIUM (Gr. *echinos*, a hedgehog; *paidion*, a child). A term applied to the embryo or larva of the Echinodermata.

ECHINOZOA (Gr. *echinos*, hedgehog; *zoa*, animals). A name proposed by Professor Allman to include the Echinoids, Asteroids, Ophiuroids, and Holothuroids.

ECHINULATE. Possessing spines.

ECTOCYST (Gr. *ektos*, outside; *kustis*, a bladder). The external investment of the cœnœcium of a *Polyzoön*.

ECTODERM (Gr. *ektos;* and *derma*, skin). The external integumentary layer of the *Cœlenterata*.

ECTOPLASM or EXOPLASM. (*See* Ectosarc).

ECTOSARC (Gr. *ektos; sarx*, flesh). The outer, transparent sarcode-layer of certain *Rhizopods*, such as the *Amœba*.

EDENTATA (Lat. *e*, without; *dens*, tooth). An order of *Mammalia*, often called *Bruta*.

EDENTULOUS. Toothless; without any dental apparatus. Applied to the mouth of any animal, or to the hinge of the Bivalve Molluscs.

EDRIOPHTHALMATA. (*See* Hedriophthalmata.)

ELASMOBRANCHII (Gr. *elasma*, a plate; *bragchia*, gill). An order of Fishes, including the Sharks and Rays.

ELYTRA (Gr. *elutron*, a sheath). The chitinous anterior pair of wings in Beetles, which form cases for the posterior membranous wings. Also applied to the scales or plates on the back of the Sea-mouse (*Aphrodite*).

EMBRYO (Gr. *en*, in; *bruo*, I swell). The earliest stage at which the young animal is recognisable in the impregnated ovum. Applied in general to the larva or young form of an animal.

ENALIOSAURIA (Gr. *enalios*, marine; *saura*, lizard). Sometimes employed as a common term to designate the extinct Reptilian orders of the *Ichthyosauria* and *Plesiosauria*.

ENCEPHALON (Gr. *egkephalos*, brain). The portion of the cerebro-spinal nervous axis contained within the cranium.

ENCEPHALOUS (Gr. *en*, in; *kephalé*, the head). Possessing a distinct head. Usually applied to all the *Mollusca* proper, except the *Lamellibranchiata*.

ENCYSTATION (Gr. *en*, in; *kustis*, a bag). The transformation undergone by certain of the *Protozoa*, when they become motionless, and surround themselves by a thick coating or cyst.

ENDERON (Gr. *en*, in; *deros*, skin). The inner plane of growth of the outer integumentary layer (viz., the ectoderm or epidermis).

ENDOCYST (Gr. *endon*, within; *kustis*, a bag). The inner membrane or integumentary layer of a *Polyzoön*. In *Cristatella*, where there is no "ectocyst," the endocyst constitutes the entire integument.

ENDODERM (Gr. *endon;* and *derma*, skin). The inner integumentary layer of the *Cœlenterata*.

ENDOPLASM. (*See* Endosarc).

ENDOPLAST (Gr. *endon*, within; *plasso*, I mould). Applied by Professor Huxley to the "nucleus" of a cell, and particularly to the "nucleus" of the *Protozoa*.

ENDOPODITE (Gr. *endon;* and *pous*, foot). The inner of the two secondary joints into which the typical limb of a *Crustacean* is divided.

ENDOSARC (Gr. *endon;* and *sarx*, flesh). The inner molecular layer of sarcode in the *Amœba*, and other allied *Rhizopods*.

ENDOSKELETON (Gr. *endon;* and *skeletos*, dry). The internal hard structures, such as bones, which serve for the attachment of muscles, or the protection of organs, and which are not a mere hardening of the integument.

ENDOSTYLE (Gr. *endon;* and *stulos*, a column). The longitudinal fold found on one side of the pharynx of the Tunicates.

ENSIFORM (Lat. *ensis*, a sword; *forma*, shape). Sword-shaped.

ENTOMOPHAGA (Gr. *entoma*, insects; *phago*, I eat). A section of the Marsupialia.

ENTOMOSTRACA (Gr. *entoma*, insects; *ostrakon*, a shell). Literally, shelled insects—applied to a division of *Crustacea*.

ENTOZOA (Gr. *entos*, within; *zoön*, animal). Animals which are parasitic in the interior of other animals.

EOCENE (Gr. *eos*, dawn; *kainos*, new or recent). The lowest division of the Tertiary rocks, in which species of existing shells are to a small extent represented.
EPHIPPIUM (Gr. *ephippion*; Lat. *ephippium*, saddle). A receptacle on the back of the *Daphnia*, in which the winter eggs are deposited.
EPIDERMIS (Gr. *epi*, upon; *derma*, the true skin). The outer, non-vascular layer of the skin, often called the scarf-skin or *cuticle*.
EPIBLAST (Gr. *epi*, upon; *blastos*, bud). The outer layer of cells (sometimes called the "serous layer") of the embryo.
EPIMERA (Gr. *epi*, upon; *mēron*, thigh). The lateral pieces of the dorsal arc of the somite of a *Crustacean*.
EPIPODIA (Gr. *epi*, upon; *pous*, the foot). Muscular lobes developed from the lateral and upper surfaces of the "foot" of some *Molluscs*.
EPIPODITE (Gr. *epi*, upon; *pous*, foot). A process developed upon the basal joint, or "protopodite," of some of the limbs of certain *Crustacea*.
EPISTERNA (Gr. *epi*, upon; *sternon*, the breast-bone). The lateral pieces of the inferior or ventral arc of the somite of a *Crustacean*.
EPISTOME (Gr. *epi*; and *stoma*, mouth). A valve-like organ which arches over the mouth in certain of the *Polyzoa*.
EPITHECA (Gr. *epi*; and *thekē*, a sheath). A continuous layer surrounding the thecæ in some Corals externally.
EPIZOA (Gr. *epi*, upon; *zoön*, animal). Animals which are parasitic upon other animals. In a restricted sense, a division of *Crustacea* which are parasitic upon fishes.
EQUILATERAL (Lat. *æquus*, equal; *latus*, side). Having its sides equal. Usually applied to the shells of the *Brachiopoda*. When applied to the spiral shells of the *Foraminifera*, it means that all the convolutions of the shell lie in the same plane.
EQUIVALVE (Lat. *æquus*, equal; *valvæ*, folding-doors). Applied to shells which are composed of two equal pieces or valves.
ERRANTIA (Lat. *erro*, I wander). An order of *Annelida*, distinguished by their great locomotive powers.
EURYPTERIDA (Gr. *eurus*, broad; *pteron*, wing). An extinct sub-order of *Crustacea*.
EXOPODITE (Gr. *exo*, outside; *pous*, foot). The outer of the two secondary joints into which the typical limb of a *Crustacean* is divided.
EXOSKELETON (Gr. *exo*, outside; *skeletos*, dry). The external skeleton, which is constituted by a hardening of the integument, and is often called a "dermoskeleton."

FALCES (Lat. *falx*, a sickle). The poison-jaws or "mandibles" of the Spiders.
FASCICULATED (Lat. *fasciculus*, a bundle). Arranged in bundles.
FAUNA (Lat. *Fauni*, the rural deities of the Romans). The general assemblage of the animals of any region or district.
FEMUR. The thigh-bone, intervening between the pelvis and the bones of the leg proper (*tibia* and *fibula*).
FERÆ (Lat. *ferus*, wild). Used often to designate the order of the *Carnivora*.
FERAL. Applied to animals which are *wild*, as opposed to those which are *domesticated*. Often applied to animals which have escaped from domestication, and have reverted to a wild condition.
FIBULA (Lat. a brooch). The outermost of the two bones of the leg in the higher *Vertebrata*, corresponding to the *ulna* of the fore-arm.
FILIFORM (Lat. *filum*, a thread; *forma*, shape). Thread-shaped.
FISSILINGUIA (Lat. *findo*, I cleave; *lingua*, tongue). A division of *Lacertilia*, with bifid tongues.
FISSION (Lat. *findo*, I cleave). Multiplication by means of a process of self-division.
FISSIPAROUS (Lat. *findo*; and *pario*, I produce). Giving origin to fresh structures by a process of fission.
FISSIROSTRAL (Lat. *findo*, I cleave; *rostrum*, beak). Applied to the widely-gaping bill of certain Birds.

FLAGELLUM (Lat. for whip). The lash-like appendage possessed by many *Infusoria*, which are therefore said to be "flagellate."
FLORA (Lat. *Flora*, the goddess of flowers). The general assemblage of the plants of any region or district.
FOOT. Applied in a special sense to the muscular mass developed on the ventral side of the body in the *Mollusca*.
FOOT-JAWS. The limbs of *Crustacea* which are modified to subserve mastication.
FOOT-TUBERCLES. The unarticulated appendages of the higher *Annelida*, often called parapodia.
FORAMINIFERA (Lat. *foramen*, an aperture; *fero*, I carry). An order of *Protozoa*, usually characterised by the possession of a shell perforated by numerous pseudopodial apertures.
FRUGIVOROUS (Lat. *frux*, fruit; *voro*, I devour). Living upon fruit.
FUNICULUS (Lat. dim. of *funis*, a rope). The cord-like structure which passes from the fundus of the stomach to the bottom of the "cell" in the *Polyzoa*.
FURCULUM or FURCULA (Lat. dim. of *furca*, a fork). The "merry-thought" of birds, or the V-shaped bone formed by the united clavicles.
FUSIFORM (Lat. *fusus*, a spindle; and *forma*, shape). Spindle-shaped, or pointed at both ends.

GALLINACEI or GALLINÆ (Lat. *gallina*, a hen). The order of Birds of which the Domestic Fowl is a typical example.
GAMOGENESIS (Gr. *gamos*, marriage; *genesis*, origin, birth). Reproduction by ova and spermatozoa; sexual reproduction.
GANGLION (Gr. *gagglion*, a knot). A mass of nervous matter containing nerve-cells, and giving origin to nerve-fibres.
GANOID (Gr. *ganos*, splendour, brightness). Applied to those scales or plates which are composed of an inferior layer of true bone covered by a superior layer of polished enamel.
GANOIDEI. An order of Fishes.
GASTROPODA (Gr. *gaster*, stomach; *pous*, foot). The class of the *Mollusca* comprising the ordinary Univalves, in which locomotion is usually effected by a muscular expansion of the under surface of the body (the "foot").
GASTRULA (Gr. dim. of *gaster*, stomach). A name applied by Haeckel to that developmental stage in various animals, in which the embryo consists of two fundamental cell-layers (ectoderm and endoderm, or epiblast and hypoblast), including a central cavity (archenteron), and communicating with the exterior by a primitive mouth-opening (blastopore).
GEMMÆ (Lat. *gemma*, a bud). The buds produced by any animal, whether detached or not.
GEMMATION. The process of producing new structures by budding.
GEMMIPAROUS (Lat. *gemma*, a bud; *pario*, I produce). Giving origin to new structures by a process of budding.
GEMMULES (Lat. dim. of *gemma*). The seed-like reproductive bodies or "spores" of *Spongilla*.
GEPHYREA (Gr. *gephura*, a bridge). A class of the *Anarthropoda*, comprising the Spoon-worms (*Sipunculus*) and their allies.
GIZZARD. A muscular division of the stomach in Birds, Insects, &c.
GLADIUS (Lat. a sword). Applied to the horny endoskeleton or "pen" of certain Cuttle-fishes.
GLENOID CAVITY (Gr. *glené*, a cavity; *eidos*, form). A shallow cavity; applied especially to the shallow articular cavity in the shoulder-blade to which the head of the humerus is jointed, or to the cavity on the temporal bone of Mammals with which the mandible articulates.
GNATHITES (Gr. *gnathos*, a jaw). The masticatory organs of *Crustacea*.
GNATHOPODS (Gr. *gnathos*, jaw; *podes*, feet). The foot-jaws of Crustaceans.
GONANGIUM (Gr. *gonos*, offspring; and *aggeion*, a vessel). The chitinous receptacle in which the reproductive buds of certain of the *Hydrozoa* are produced.
GONOBLASTIDIA (Gr. *gonos*, offspring; *blastidion*, dim. of *blastos*, a bud). The

processes which carry the reproductive receptacles, or "gonophores," in many of the *Hydrozoa*.

GONOCALYX (Gr. *gonos;* and *kalux*, cup). The swimming-bell in a medusiform gonophore, or the same structure in a gonophore which is not detached.

GONOPHORE (Gr. *gonos;* and *phero*, I carry). The generative buds, or receptacles of the reproductive elements, in the *Hydrozoa*, whether these become detached or not.

GONOSOME (Gr. *gonos;* and *soma*, body). Applied as a collective term to the reproductive zoöids of a *Hydrozoön*.

GONOTHECA (Gr. *gonos;* and *theké*, a case). The chitinous receptacle within which the gonophores of certain of the *Hydrozoa* are produced.

GRALLÆ or GRALLATORES (Lat. *grallæ*, stilts). An order of Birds, including many long-legged forms.

GRANIVOROUS (Lat. *granum*, a grain or seed; *voro*, I devour). Living upon grains or other seeds.

GRAPTOLITOIDEA (Gr. *grapho*, I write; *lithos*, a stone; *eidos*, form). The "Graptolites," a sub-class of extinct *Hydrozoa*.

GREGARINIDA (Lat. *gregarius*, occurring in numbers together). A class of the *Protozoa*.

GUARD. The cylindrical fibrous sheath with which the internal chambered shell (phragmacone) of a *Belemnite* is protected.

GYMNOBLASTIC (Gr. *gumnos*, naked; and *blastos*, a bud). Applied by Prof. Allman to those *Hydrozoa* in which the nutritive and reproductive buds are not protected by horny receptacles.

GYMNOCYTE (Gr. *gumnos*, naked; *kutos*, a vessel). A naked, nucleated mass of protoplasm, without a proper "wall."

GYMNOLÆMATA (Gr. *gumnos*, naked; *laimos*, the throat). An order of the *Polyzoa* in which the mouth is devoid of the valvular structure known as the "epistome."

GYMNOPHIONA (Gr. *gumnos*, naked; *ophis*, a snake). The order of the *Amphibia* comprising the snake-like *Cæciliæ*.

GYMNOPHTHALMATA (Gr. *gumnos;* and *ophthalmos*, the eye). Applied by Edward Forbes to those *Medusæ* in which the eye-specks at the margin of the disc are unprotected. The division is now abandoned.

GYMNOSOMATA (Gr. *gumnos;* and *soma*, the body). The order of *Pteropoda* in which the body is not protected by a shell.

GYNOPHORES (Gr. *guné*, woman; *phero*, I carry). The generative buds, or gonophores of *Hydrozoa* which contain ova alone, and differ in form from those which contain spermatozoa.

GYRENCEPHALA (Gr. *guroo*, I wind about; *egkephalos*, brain). Applied by Owen to a section of the Mammalia in which the cerebral hemispheres are abundantly convoluted.

HÆMAL (Gr. *haima*, blood). Connected with the blood-vessels, or with the circulatory system.

HÆMATOCRYA (Gr. *haima*, blood; *cruos*, cold). Applied by Owen to the "cold-blooded" Vertebrates—viz., the Fishes, Amphibia, and Reptiles.

HÆMATOTHERMA (Gr. *haima*, blood; *thermos*, warm). Applied by Owen to the "warm-blooded" Vertebrates—viz., Birds and Mammals.

HALLUX (Lat. *allex*, the thumb or great toe). The innermost of the five digits which normally compose the *hind* foot of a Vertebrate animal. In man, the great toe.

HALTERES (Gr. *haltēres*, weights used by athletes to steady themselves in leaping). The rudimentary filaments or "balancers" which represent the posterior pair of wings in the *Diptera*, an order of Insects.

HAUSTELLATE (Lat. *haurio*, I drink). Adapted for sucking or pumping up fluids; applied to the mouth of certain *Crustacea* and *Insecta*.

HECTOCOTYLUS (Gr. *hekaton*, a hundred; *kotulos*, a cup). The metamorphosed reproductive arm of certain of the male Cuttle-fishes. In the *Argonaut* the arm becomes detached, and was originally described as a parasitic worm.

HEDRIOPHTHALMATA (Gr. *hedraios*, sitting; *ophthalmos*, eye). The division

of Crustaceans in which the eyes are sessile, and are not supported upon stalks.

HELIOZOA (Gr. *hēlios*, sun; *zoön*, animal). An order of *Protozoa*, with radiating pseudopodia.

HELMINTHOID (Gr. *helmins*, an intestinal worm). Worm-shaped, vermiform.

HEMELYTRA (Gr. *hemi*, half; *elutron*, a sheath). The wings of certain Insects, in which the apex of the wing is membranous, whilst the inner portion is chitinous, and resembles the elytron of a beetle.

HEMIMETABOLIC (Gr. *hemi*, half; *metabolé*, change). Applied to those Insects which undergo an incomplete metamorphosis.

HEMIPTERA (Gr. *hemi;* and *pteron*, wing). An order of Insects in which the anterior wings are sometimes "hemelytra."

HERMAPHRODITE (Gr. *Hermes*, Mercury; *Aphrodite*, Venus). Possessing the generative organs of both sexes combined.

HETEROCERA (Gr. *heteros*, diverse; *keras*, horn). Applied to the Moths amongst the *Lepidoptera*, on account of the great variety of shape in their antennæ.

HETEROCERCAL (Gr. *heteros*, diverse; *kerkos*, tail). Applied to the tail of Fishes when it is unsymmetrical, or composed of two unequal lobes.

HETEROGANGLIATE (Gr. *heteros*, diverse; *gagglion*, a knot). Possessing a nervous system in which the ganglia are scattered (as in the *Mollusca*, for example).

HETEROGENESIS or HETEROGENY (Gr. *heteros*, diverse; *genesis*, origin, birth). The production of living beings without pre-existent living beings.

HETEROMORPHIC (Gr. *heteros; morphé*, form). Differing in form and shape.

HETEROMYARY (Gr. *heteros*, diverse; *muon*, muscle). Applied to those Bivalves in which the anterior adductor is much smaller than the posterior adductor.

HETEROPHAGI (Gr. *heteros*, other; *phago*, I eat). Applied to Birds, the young of which are born in a helpless condition, and require to be fed by the parents for a longer or shorter period.

HETEROPODA (Gr. *heteros*, diverse; *podes*, feet). An aberrant group of the Gastropods, in which the foot is modified so as to form a swimming organ.

HEXAPOD (Gr. *hex*, six; *pous*, foot). Possessing six legs; applied to the *Insecta*.

HIBERNATION (Lat. *hiberno*, I pass the winter). The winter torpidity exhibited by many animals in the winter season in cold regions.

HILUM (Lat. *hilum*, a little thing). A small aperture (as in the gemmules of sponges), or a small depression (as in *Noctiluca*).

HIRUDINEA (Lat. *hirudo*, a horse-leech). The order of *Annelida* comprising the Leeches.

HISTOLOGY (Gr. *histos*, a web; *logos*, a discourse). The study of the tissues, more especially of the minuter elements of the body.

HOLOCEPHALI (Gr. *holos*, whole; *kephalé*, head). A sub-order of the *Elasmobranchii* comprising the *Chimæræ*.

HOLOMETABOLIC (Gr. *holos*, whole; *metabolé*, change). Applied to Insects which undergo a complete metamorphosis.

HOLOSTOMATA (Gr. *holos*, whole; *stoma*, mouth). A division of *Gastropodous Molluscs*, in which the aperture of the shell is rounded or "entire."

HOLOTHUROIDEA (Gr. *holothourion;* and *eidos*, form). An order of *Echinodermata*, comprising the Trepangs and Sea-cucumbers.

HOMOCERCAL (Gr. *homos*, same; *kerkos*, tail). Applied to the tail of Fishes when it is symmetrical, or composed of two equal lobes.

HOMOGANGLIATE (Gr. *homos*, like; *gagglion*, a knot). Having a nervous system in which the ganglia are symmetrically arranged (as in the *Annulosa*, for example).

HOMOLOGOUS (Gr. *homos;* and *logos*, a discourse). Applied to parts which are constructed upon the same fundamental plan.

HOMOMORPHOUS (Gr. *homos;* and *morphé*, form). Having a similar external appearance or form.

HUMERUS. The bone of the upper arm (*brachium*) in the Vertebrates.

HYALINE (Gr. *hualos*, crystal). Crystalline or glassy.

HYDATID (Gr. *hudatis*, a vesicle). The bladder-like structure produced by the budding scolices of certain of the Tape-worms.

HYDRAFORM. Resembling the common Fresh-water Polype (*Hydra*) in form.

HYDRANTH (Gr. *hudra*, water-serpent; and *anthos*, flower). The "polypite," or proper nutritive zoöid, of the *Hydrozoa*.

HYDROCAULUS (Gr. *hudra*, a water-serpent; and *kaulos*, a stem). The main stem of the cœnosarc of a *Hydrozoön*.

HYDROCYSTS (Gr. *hudra*; and *kustis*, a cyst). Curious sensory processes attached to the cœnosarc of the *Physophoridæ*.

HYDRŒCIUM (Gr. *hudra*; and *oikos*, a house). The chamber into which the cœnosarc in many of the *Calycophoridæ* can be retracted.

HYDROIDA (Gr. *hudra*; and *eidos*, form). The sub-class of the *Hydrozoa* which comprises the animals most nearly allied to the *Hydra*.

HYDROPHYLLIA (Gr. *hudra*; and *phullon*, a leaf). Overlapping appendages or plates which protect the polypites in some of the oceanic *Hydrozoa* (*Calycophoridæ* and *Physophoridæ*). They are often termed "bracts," and are the "*Deckstücke*" of the Germans.

HYDRORHIZA (Gr. *hudra*; and *rhiza*, root). The adherent base or proximal extremity of any *Hydrozoön*.

HYDROSOMA (Gr. *hudra*; and *soma*, body). The entire organism of any *Hydrozoön*.

HYDROTHECÆ (Gr. *hudra*; and *thekê*, a case). The little chitinous cups in which the polypites of the *Sertularida* and *Campanularida* are protected.

HYDROZOA (Gr. *hudra*; and *zoön*, animal). The class of the *Cœlenterata* which comprises animals constructed after the type of the *Hydra*.

HYMENOPTERA (Gr. *humen*, a membrane; *pteron*, a wing). An order of Insects (comprising Bees, Ants, &c.) characterised by the possession of four membranous wings.

HYOID (Gr. *U*; *eidos*, form). The bone which supports the tongue in Vertebrates, and derives its name from its resemblance in man to the Greek letter U.

HYPOBLAST (Gr. *hupo*, under; *blastos*, bud). The inner of the two fundamental cell-layers of the embryo.

HYPOSTOME (Gr. *hupo*, under; *stoma*, mouth). The upper lip, or "labrum," of the *Crustacea*.

HYRACOIDEA (Gr. *hurax*, a shrew; *eidos*, form). An order of the *Mammalia* constituted for the reception of the single genus *Hyrax*.

ICHTHYODORULITE (Gr. *ichthus*, fish; *doru*, spear; *lithos*, stone). The fossil fin-spines of Fishes.

ICHTHYOMORPHA (Gr. *ichthus*; *morphê*, shape). An order of Amphibians, often called *Urodela*, comprising the fish-like Newts, &c.

ICHTHYOPHTHIRA (Gr *ichthus*; *phtheir*, a louse). A parasitic group of Copepod Crustaceans.

ICHTHYOPSIDA (Gr. *ichthus*; *opsis*, appearance). The primary division of *Vertebrata*, comprising the Fishes and Amphibia. Often spoken of as the *Branchiate Vertebrata*.

ICHTHYOPTERYGIA (Gr. *ichthus*; *pterux*, wing). An extinct order of Reptiles.

ICHTHYOSAURIA (Gr. *ichthus*; *saura*, lizard). Synonymous with *Ichthyopterygia*.

ILIUM. The haunch-bone, one of the bones of the pelvic arch in the higher Vertebrates.

IMAGO (Lat. an image or apparition). The perfect insect, after it has undergone its metamorphoses.

IMBRICATED. Applied to scales or plates which overlap one another like tiles.

INCISOR (Lat. *incido*, I cut). The cutting-teeth fixed in the præmaxillary bones of the *Mammalia*, and the corresponding teeth in the lower jaw.

INEQUILATERAL. Having the two sides unequal, as in the case of the shells of the ordinary Bivalves (*Lamellibranchiata*). When applied to the shells

of the *Foraminifera*, it implies that the convolutions of the shell do not lie in the same plane, but are obliquely wound round an axis.
INEQUIVALVE. Composed of two unequal pieces or valves.
INFUNDIBULUM (Lat. for funnel). The tube formed by the coalescence or apposition of the epipodia in the *Cephalopoda*—commonly termed the "funnel" or "siphon."
INFUSORIA (Lat. *infusum*, an infusion). A class of *Protozoa*, so called because they are often developed in organic infusions.
INGLUVIES (Lat. the crop). A dilatation of the gullet ("crop"), found in Birds, Insects, &c.
INGUINAL (Lat. *inguen*, groin). Connected with, or situated upon, the groin.
INOPERCULATA (Lat. *in*, without; *operculum*, a lid). The division of pulmonate *Gastropoda* in which there is no shelly or horny plate (operculum) by which the shell is closed when the animal is withdrawn within it.
INSECTA (Lat. *inseco*, I cut into). The class of Articulate animals commonly known as Insects.
INSECTIVORA (Lat. *insectum*, an insect; *voro*, I devour). An order of Mammals.
INSECTIVOROUS. Living upon Insects.
INSESSORES (Lat. *insideo*, I sit upon). The order of the Perching Birds, often called *Passeres*.
INTERAMBULACRA. The rows of plates in an *Echinoid* which are not perforated for the emission of the "tube-feet."
INTERMAXILLÆ. (*See* Præmaxillæ.)
INTERRADIAL. Applied to structures in the Echinoderms which are situated between the "radii" or radiating segments, of which the body of one of these animals is made up.
INTUSSUSCEPTION (Lat. *intus*, within; *suscipio*, I take up). The act of taking foreign matter into a living being.
INVERTEBRATA (Lat. *in*, without; *vertebra*, a bone of the back). Animals without a spinal column or backbone.
ISCHIUM (Gr. *ischion*, the hip). One of the bones of the pelvic arch in Vertebrates.
ISOPODA (Gr. *isos*, equal; *podes*, feet). An order of *Crustacea*, in which the feet are often like one another and equal.

JUGULAR (Lat. *jugulum*, the throat). Connected with, or placed upon, the throat. Applied to the ventral fins of fishes when they are placed beneath or in advance of the pectorals.

KAINOZOIC (Gr. *kainos*, recent; *zoë*, life). The Tertiary period in Geology, comprising those formations in which the organic remains approximate more or less closely to the existing fauna and flora.
KERATODE (Gr. *keras*, horn; *eidos*, form). The horny substance of which the skeleton of many Sponges is made up.

LABIUM (Lat. for lip). Restricted to the lower lip of Arthropods.
LABRUM (Lat. for lip). Restricted to the upper lip of Arthropods.
LABYRINTHODONTIA (Gr. *laburinthos*, a labyrinth; *odous*, tooth). An extinct order of *Amphibia*, so called from the complex microscopic structure of the teeth.
LACERTILIA (Lat. *lacerta*, a lizard). An order of *Reptilia* comprising the Lizards and Slow-worms.
LÆMODIPODA (Gr. *laimos*, throat; *dis*, twice; *podes*, feet). A group of *Crustacea*, so called because they have two feet placed far forwards, as it were under the throat.
LAMELLIBRANCHIATA (Lat. *lamella*, a plate; Gr. *bragchia*, gill). The class of *Mollusca*, comprising the ordinary Bivalves, characterised by the possession of lamellar gills.
LAMELLIROSTRES (Lat. *lamella*, a plate; *rostrum*, beak). The flat-billed Swimming Birds (*Natatores*), such as Ducks, Geese, Swans, &c.
LARVA (Lat. a mask). The insect in its first stage after its emergence from

the egg, when it is usually very different from the adult. Applied in a general sense to the young form of any animal, particularly if unlike the adult.

LARYNX. The upper part of the windpipe, forming a cavity with appropriate muscles and cartilages, situated beneath the hyoid bone, and concerned in Mammals in the production of vocal sounds.

LEMUROIDEA (Lat. *lemures*, ghosts; Gr. *eidos*, form). The division of *Primates* of which the Lemurs are the type.

LENTICULAR (Lat. *lens*, a bean). Shaped like a biconvex lens.

LEPIDOPTERA (Gr. *lepis*, a scale; *pteron*, a wing). An order of Insects, comprising Butterflies and Moths, characterised by possessing four wings which are usually covered with minute scales.

LEPTOCARDIA (Gr. *leptos*, slender, small; *cardia*, heart). The name given by Müller to the order of Fishes comprising the Lancelet, now called *Pharyngobranchii.*

LIGAMENTUM NUCHÆ (Lat. *nucha*, the nape of the neck). The band of elastic fibres by which the weight of the head in *Mammalia* is supported.

LINGUAL (Lat. *lingua*, the tongue). Connected with the tongue.

LISSENCEPHALA (Gr. *lissos*, smooth; *egkephalos*, brain). A primary division of *Mammalia*, according to Owen, in which the cerebral hemispheres are smooth or have few convolutions.

LITHOCYSTS (Gr. *lithos*, a stone; *kustis*, a cyst). The sense-organs or "marginal bodies" of the *Lucernarida* or *Steganophthalmate Medusæ.*

LONGIPENNATÆ (Lat. *longus*, long; *penna*, wing). A group of the Natatorial Birds.

LONGIROSTRAL (Lat. *longus; rostrum*, beak). Applied to the slender and soft-tipped beak of Snipes and allied birds.

LOPHOPHORE (Gr. *lophos*, a crest; and *phero*, I carry). The disc or stage upon which the tentacles of the *Polyzoa* are borne.

LOPHYROPODA (Gr. *lophouros*, having stiff hairs; and *podes*, feet). A section of *Crustacea.*

LORICA (Lat. a breast-plate). Applied to the protective case with which certain *Infusoria* are provided.

LORICATA (Lat. *lorica*, a cuirass). The division of Reptiles comprising the *Chelonia* and *Crocodilia*, in which bony plates are developed in the skin (*dermis*).

LUCERNARIDA (Lat. *lucerna*, a lamp). A division of the *Hydrozoa.*

LUMBAR (Lat. *lumbus*, loin). Connected with the loins.

LUNATE (Lat. *luna*, moon). Crescentic in shape.

LYENCEPHALA (Gr. *luo*, I loose; *egkephalos*, brain). A primary division of Mammals according to Owen.

MACRURA (Gr. *makros*, long; *oura*, tail). A tribe of Decapod *Crustaceans* with long tails (*e.g.*, the Lobster, Shrimp, &c.)

MADREPORIFORM. Perforated with small holes, like a coral; applied to the tubercle ("madreporite") by which the ambulacral system of the *Echinoderms* mostly communicates with the exterior.

MALACOSTRACA (Gr. *malakos*, soft; *ostrakon*, shell). A division of *Crustacea.* Originally applied by Aristotle to the entire class *Crustacea*, because their shells were softer than those of the *Mollusca.*

MALLOPHAGA (Gr. *mallos*, a fleece; *phago*, I eat). An order of Insects which are mostly parasitic upon birds.

MAMMALIA (Lat. *mamma*, the breast). The class of Vertebrate animals which suckle their young.

MANDIBLE (Lat. *mandibulum*, a jaw). The first pair of jaws in Insects; also applied to one of the pairs of jaws in *Crustacea* and Spiders, to the beak of Cephalopods, the lower jaw of Vertebrates, &c.

MANTLE. The dorsal integument of most of the Mollusca, which is largely developed, and forms a cloak in which the viscera are protected. Technically called the "pallium."

MANUBRIUM (Lat. a handle). The polypite which is suspended from the roof

of the swimming-bell of a *Medusa*, or from the gonocalyx of a medusiform gonophore, amongst the *Hydrozoa*.

MANUS (Lat. the hand). The hand or fore-foot of the higher Vertebrates.

MARSIPOBRANCHII (Gr. *marsipos*, a pouch; *bragchia*, gill). The order of Fishes comprising the Hag-fishes and Lampreys, with pouch-like gills.

MARSUPIALIA (Lat. *marsupium*, a pouch). An order of Mammals in which the females mostly have an abdominal pouch in which the young are carried.

MASTAX (Gr. mouth). The muscular pharynx or "buccal funnel" into which the mouth opens in most of the *Rotifera*.

MASTICATORY (Lat. *mastico*, I chew). Applied to parts adapted for chewing.

MAXILLÆ (Lat. jaws). The inferior pair or pairs of jaws in the *Arthropoda* (Insects, Crustacea, &c.) The upper jaw-bones of Vertebrates.

MAXILLIPEDES (Lat. *maxillæ*, jaws; *pes*, the foot). The limbs in *Crustacea* and *Myriopoda* which are converted into masticatory organs, and are commonly called "foot-jaws."

MEDULLA (Lat. marrow). Applied to the marrow of bones; or to the spinal cord, with or without the adjective "*spinalis*."

MEDUSÆ. The "Jelly-fishes," so called because of the resemblance of their tentacles to the snaky hair of the Medusa. Some Jelly-fishes (*Trachymedusæ*) are independent animals; but others are merely a single life-stage in certain of the *Hydrozoa*.

MEDUSIFORM. Resembling a *Medusa* in shape.

MEDUSOID. Like a *Medusa*; used substantively to designate the medusiform gonophores of the *Hydrozoa*.

MEMBRANA NICTITANS (Lat. *nicto*, I wink). The third eyelid of birds, &c.

MENTUM (Lat. the chin). The basal portion of the labium or lower lip in Insects. The chin in man.

MEROSTOMATA (Gr. *mēron*, thigh; *stoma*, mouth). An order of *Crustacea* in which the appendages which are placed round the mouth, and which officiate as jaws, have their free extremities developed into walking or prehensile organs.

MESENTERIES (Gr. *mesos*, intermediate; *enteron*, intestine). In a restricted sense, the vertical plates which divide the somatic cavity of an Actinozoön. In a general sense, the membrane by which the alimentary canal is connected with the wall of the body.

MESOBLAST (Gr. *mesos*, intermediate; *blastos*, bud). The middle layer of cells ("vascular layer") in the embryo of the higher *Metazoa*.

MESODERM (Gr. *mesos*; and *derma*, skin). The middle layer of the body-wall of a Cœlenterate animal. It is developed between the ectoderm and endoderm, and consists essentially of connective tissue.

MESOPODIUM (Gr. *mesos*; and *pous*, foot). The central portion of the "foot" of the Gastropodous Molluscs.

MESOSTERNUM (Gr. *mesos*, intermediate; *sternon*, the breast-bone). The middle portion of the sternum, intervening between the attachment of the second pair of ribs and the xiphoid cartilage (*xiphisternum*).

MESOTHORAX (Gr. *mesos*; and *thorax*, the chest). The middle ring of the thorax in Insects.

MESOZOIC (Gr. *mesos*; and *zoē*, life). The Secondary period in Geology.

METACARPUS (Gr. *meta*, after; *karpos*, the wrist). The bones which intervene between the wrist (*carpus*) and the fingers.

METAMORPHOSIS (Gr. *meta*, implying change; *morphē*, shape). The changes of form which certain animals undergo in passing from their younger to their fully-grown condition.

METAPODIUM (Gr. *meta*, after; *pous*, the foot). The posterior lobe of the foot in *Mollusca*; often called the "operculigerous lobe," because it develops the operculum when this structure is present.

METASTOMA (Gr. *meta*, after; *stoma*, mouth). The plate which closes the mouth posteriorly in the *Crustacea*.

METATARSUS (Gr. *meta*, after; *tarsos*, the instep). The bones which intervene between the bones of the ankle (*tarsus*) and the digits in the hind-foot of the higher Vertebrates.

METATHORAX (Gr. *meta*, after ; *thorax*, the chest). The posterior ring of the thorax in Insects.
METAZOA (Gr. *meta*, implying change ; *zoön*, animal). Applied to animals in which the primitive indifferent tissue of the embryo becomes converted into cells, which in turn may or may not be developed into more complex tissues. Under this head are included all animals except the *Protozoa*.
MOLARS (Lat. *mola*, a mill). The back teeth of the milk-dentition. Those back teeth of the permanent dentition which are not preceded by milk-teeth.
MOLLUSCA (Lat. *mollis*, soft). The sub-kingdom of the Shell-fish (*Testacea*). The name is in allusion to the generally soft nature of the body.
MOLLUSCOIDEA (*Mollusca;* Gr. *eidos*, form). A name used by many naturalists for the *Brachiopoda* and *Polyzoa*, with or without the Tunicates.
MONADS (Gr. *monas*, unity). Unicellular microscopic animals, furnished with a single flagellum.
MONERA (Gr. *monēres*, single). An order of Protozoa, comprising animals composed of simple undifferentiated sarcode.
MONOCULOUS. Possessed of only one eye.
MONODELPHIA (Gr. *monos*, single ; *delphus*, womb). The division of *Mammalia* in which the uterus is single.
MONŒCIOUS (Gr. *monos*, single; *oikos*, house). Applied to individuals in which the sexes are united.
MONOMYARY (Gr. *monos*, single ; *muon*, muscle). Applied to those Bivalves (*Lamellibranchiata*) in which the shell is closed by a single adductor muscle.
MONOPHYODONT (Gr. *monos ; phuo*, I generate ; *odous*, tooth). Applied to those Mammals in which only a single set of teeth is ever developed.
MONOTHALAMOUS (Gr. *monos ;* and *thalamos*, chamber). Possessing only a single chamber. Applied to the shells of *Foraminifera* and *Mollusca*.
MONOTREMATA (Gr. *monos ; trema*, aperture). The order of Mammals comprising the Duck-mole and *Echidna*, in which the intestinal canal opens into a "cloaca" common to the ducts of the urinary and generative organs.
MORPHOLOGICAL (Gr. *morphé*, shape ; *logos*, discourse). Relating to form and *structure*, as opposed to *function*.
MORULA (Lat. dim. of *morus*, a mulberry). Applied to ova in which the primitive segmentation-spheres do not become arranged so as to give rise to a "segmentation-cavity," but the segmented ovum is solid.
MULTILOCULAR (Lat. *multus*, many; *loculus*, a little purse). Divided into many chambers.
MULTIVALVE. Applied to shells which are composed of many pieces.
MULTUNGULA (Lat. *multus*, many ; *ungula*, hoof). The division of Perissodactyle Ungulates, in which each foot has more than a single hoof.
MYELON (Gr. *muelos*, marrow). The spinal cord of Vertebrates.
MYRIOPODA or MYRIAPODA (Gr. *murios*, ten thousand ; *podes*, feet). A class of *Arthropoda* comprising the Centipedes and their allies, characterised by their numerous feet.

NACREOUS (Fr. *nacre*, mother-of-pearl, originally Oriental). Pearly ; of the texture of mother-of-pearl.
NATATORES (Lat. *nare*, to swim). The order of the Swimming Birds.
NATATORY (Lat. *nare*, to swim). Formed for swimming.
NAUPLIUS (Lat. a species of Shell-fish). The unsegmented ovate larva of the lower Crustaceans, in which there is a median eye and three pairs of appendages.
NAUTILOID. Resembling the shell of the *Nautilus* in shape.
NECTOCALYX (Gr. *necho*, I swim ; *kalux*, cup). The swimming-bell or "disc" of a *Medusa* or Jelly-fish.
NEMATELMIA (Gr. *nema*, thread ; *helmins*, a worm). The division of *Scolecida* comprising the Round-worms, Thread-worms, &c.
NEMATOCYSTS (Gr. *nema*, thread ; *kustis*, a bag). The thread-cells of the *Cœlenterata*. (*See* Cnidæ.)
NEMATOIDEA (Gr. *nema*, thread ; *eidos*, form). An order of *Scolecida* comprising the Thread-worms, Vinegar-eels, &c.

NEMATOPHORES (Gr. *nema*, thread ; *phero*, I carry). Cæcal processes found on the cœnosarc of certain of the *Sertularida*, containing numerous thread-cells at their extremities.
NEMERTIDA (Gr. *Nemertes*, proper name). A division of the *Turbellarian Worms*, commonly called "Ribbon-worms."
NEPHRIDIA (Gr. *nephros*, kidney). The tubular organs ("segmental organs," &c.) which are believed to correspond in many Invertebrates with the kidneys of the Vertebrates.
NERVURES (Lat. *nervus*, a sinew). The ribs which support the membranous wings of insects.
NEURAL (Gr. *neuron*, a nerve). Connected with the nervous system.
NEURAPOPHYSIS (Gr. *neuron*, a nerve ; *apophusis*, a projecting part). The "spinous process" of a vertebra, or the process formed at the point of junction of the neural arches.
NEUROPODIUM (Gr. *neuron*, a nerve ; *pous*, the foot). The ventral or inferior division of the "foot-tubercle" of an *Annelide ;* often called the "ventral oar."
NEUROPTERA (Gr. *neuron ;* and *pteron*, a wing). An order of insects characterised by four membranous wings with numerous reticulated nervures (*e.g.*, Dragon-flies).
NEUTER (Lat. neither the one nor the other). Having no fully developed sex.
NIDIFICATION (Lat. *nidus*, a nest ; *facio*, I make). The building of a nest.
NOCTURNAL (Lat. *nox*, night). Applied to animals which are active by night.
NORMAL (Lat. *norma*, a rule). Conforming to the ordinary standard.
NOTOBRANCHIATA (Gr. *notos*, the back ; and *bragchia*, gill). Carrying the gills upon the back ; applied to a division of the *Annelida*.
NOTOCHORD (Gr. *notos*, the back ; *chordé*, string). A cellular rod which is developed in the embryo of Vertebrates immediately beneath the spinal cord, and which is usually replaced in the adult by the vertebral column. Often it is spoken of as the "chorda dorsalis."
NOTOPODIUM (Gr. *notos*, the back ; and *pous*, the foot). The dorsal division of one of the foot-tubercles or parapodia of an *Annelide ;* often called the "dorsal oar."
NUCHAL (Lat. *nucha*, the nape of the neck). Applied to structures situated on the nape of the neck.
NUCLEATED. Possessing a nucleus or central particle.
NUCLEOLUS. The minute solid or vesicular body in the interior of the nucleus of a cell.
NUCLEUS (Lat. a kernel). 1. The solid or vesicular body found in the interior of many cells. 2. The "madreporite" of the Echinoderms. 3. The embryonic shell which is retained in many Molluscs to form the apex of the adult shell.
NUDIBRANCHIATA (Lat. *nudus*, naked ; and Gr. *bragchia*, gill). An order of the *Gastropoda* in which the gills are naked.
NYMPH. The active pupa of certain Insects.

OCCIPITAL. Connected with the *occiput* or the back part of the head.
OCEANIC. Applied to animals which inhabit the open ocean (=pelagic).
OCELLI (Lat. diminutive of *oculus*, eye). The simple eyes of many Echinoderms, Spiders, Crustaceans, Molluscs, &c.
OCTOPODA (Gr. *octo*, eight ; *pous*, foot). The tribe of Cuttle-fishes with eight arms attached to the head.
ODONTOCETI (Gr. *odous*, tooth ; *ketos*, whale). The "toothed" Whales, in contradistinction to the "whalebone" Whales.
ODONTOID (Gr. *odous ; eidos*, form). "The odontoid process" is the centrum or body of the first cervical vertebra (*atlas*). It is detached from the atlas, and is often anchylosed with the second cervical vertebra (*axis*), and it forms the pivot upon which the head rotates.
ODONTOPHORA. A name given by Professor Huxley to the *Gastropoda*, *Pteropoda*, and *Cephalopoda* collectively, from the presence in these groups of the

structure known as the "odontophore." The name "Glossophora" has been proposed by Professor Ray Lankester for the same groups.

ODONTOPHORE (Gr. *odous*, tooth; *phero*, I carry). The peculiar masticatory apparatus of the Molluscs (exclusive of the Bivalves).

ODONTORNITHES (Gr. *odous*, tooth; *ornis*, bird). An extinct sub-class of Birds, comprising forms with distinct teeth in sockets or in a groove.

ŒSOPHAGUS. The gullet or tube leading from the mouth to the stomach.

OLIGOCHÆTA (Gr. *oligos*, few; *chaitê*, hair). An order of *Annelida*, comprising the Earth-worms, in which there are few bristles.

OMASUM (Lat. bullock's-tripe). The third stomach of Ruminants, commonly called the *psalterium*, or manyplies.

OMNIVOROUS (Lat. *omnia*, everything; *voro*, I devour). Feeding indiscriminately upon all sorts of food.

ONTOGENESIS (Gr. *onta*, beings; *genesis*, birth). The development of the *individual*, as opposed to the development of the *species*.

ONYCHOPHORA (Gr. *onux*, claw or nail; *phero*, I carry). The order of which *Peripatus*, with its hooked feet, is the type.

OOCYSTS (Gr. *oön*, egg; *kustis*, bladder). Chambers appended to the cells of certain of the Polyzoa, which serve as a receptacle for the eggs. Sometimes called "ovicells" or "oœcia."

OPERCULATA (Lat. *operculum*, a lid). A division of pulmonate *Gastropoda*, in which the shell is closed by an operculum.

OPERCULUM. A horny or shelly plate developed in certain *Mollusca* upon the hinder part of the foot, and serving to close the aperture of the shell when the animal is retracted within it; also the lid of the shell of a *Balanus* or Acorn-shell; also the chain of flat bones which covers the gills in many fishes.

OPHIDIA (Gr. *ophis*, a serpent). The order of Reptiles comprising the Snakes.

OPHIOMORPHA (Gr. *ophis; morphê*, shape). The order of *Amphibia* comprising the *Cœciliæ*.

OPHIUROIDEA (Gr. *ophis*, snake; *oura*, tail; *eidos*, form). An order of *Echinodermata* comprising the Brittle-stars and Sand-stars.

OPISTHOBRANCHIATA (Gr. *opisthen*, behind; *bragchia*, gill). A division of *Gastropoda*, in which the gills are placed on the posterior part of the body.

OPISTHOCŒLOUS (Gr. *opisthen*, behind; *koilos*, hollow). Applied to vertebræ the bodies of which are hollow or concave behind.

ORAL (Lat. *os*, mouth). Connected with the mouth.

ORNITHODELPHIA (Gr. *ornis*, a bird; *delphus*, womb). The primary division of Mammals comprising the *Monotremata*.

ORTHOCERATIDÆ (Gr. *orthos*, straight; *keras*, horn). A family of the *Nautilidæ*, in which the shell is straight, or nearly so.

ORTHOPTERA (Gr. *orthos*, straight; *pteron*, wing). An order of Insects.

OSCULA (Lat. diminutive of *os*, mouth). 1. The large apertures by which a sponge is perforated ("exhalant apertures"). 2. The suckers with which the *Tæniada* (Tape-worms and Cystic Worms) are provided.

OSSICULA (Lat. diminutive of *os*, bone). Literally small bones. Often used to designate any hard structures of small size, such as the calcareous plates in the integument of the Star-fishes.

OSTRACODA (Gr. *ostrakon*, a shell). An order of small Crustaceans which are enclosed in bivalve shells.

OTOCYST (Gr. *ous*, ear; *kustis*, bladder). A simple form of auditory apparatus, consisting of a membranous sac or vesicle, filled with fluid and containing mineral particles in its interior.

OTOLITHS (Gr. *ous*, ear; and *lithos*, stone). The calcareous bodies connected with the sense of hearing, even in its most rudimentary form.

OVARIAN VESICLES OR CAPSULES. The reproductive buds of the *Sertularida*.

OVARY (OVARIUM). The organ by which ova are produced.

OVIPAROUS (Lat. *ovum*, an egg; and *pario*, I bring forth). Applied to animals which bring forth eggs, in contradistinction to those which bring forth their young alive.

OVIPOSITOR (Lat. *ovum;* and *pono*, I place). The organ possessed by some In-

sects, by means of which the eggs are placed in a position suitable for their development.

OVISAC. The external bag or sac in which certain of the Invertebrates carry their eggs after they are extruded from the body.

OVOVIVIPAROUS (Lat. *ovum*, egg; *vivus*, alive; *pario*, I produce). Applied to animals which retain their eggs within the body until they are hatched.

OVUM (Lat. an egg). The germ produced within the ovary, and capable under certain conditions of being developed into a new individual.

PACHYDERMATA (Gr. *pachus*, thick; *derma*, skin). An old Mammalian order constituted by Cuvier for the reception of the Rhinoceros, Hippopotamus, Elephant, &c.

PALÆONTOLOGY (Gr. *palaios*, ancient; *onta*, beings; and *logos*, discourse). The science of fossil remains or of extinct organised beings.

PALÆOZOIC (Gr. *palaios*, ancient; and *zoé*, life). Applied to the oldest of the great palæontological epochs.

PALI (Lat. *palus*, a stake). Vertical calcareous plates which in certain Corals are developed in a cycle internal to the free edges of the proper septa.

PALLIOBRANCHIATA (Lat. *pallium*, a cloak; and Gr. *bragchia*, gill). An old name for the *Brachiopoda*, founded upon the belief that the system of tubes in the mantle constituted the gills.

PALLIUM (Lat. a cloak). The mantle of the *Mollusca*. *Pallial:* relating to the mantle. *Pallial line* or *impression:* the line left in the dead shell by the muscular margin of the mantle. *Pallial shell:* a shell which is secreted by, or contained within, the mantle, such as the "bone" of the Cuttle-fishes.

PALPI (Lat. *palpo*, I touch). Processes supposed to be organs of touch, developed from certain of the oral appendages in Insects, Spiders, and Crustacea, and from the sides of the mouth in the Acephalous Molluscs.

PANSPERMY (Gr. *pan*, all; *sperma*, seed). The theory that living beings are never produced except from pre-existent living beings.

PAPILLA (Lat. for nipple). A minute soft prominence.

PARANUCLEUS. The so-called "nucleolus" of the *Infusoria*, which may be contained in the interior of the nucleus, or may be applied to its exterior, or may simply be near (Gr. *para*, beside) the latter.

PARAPODIA (Gr. *para*, beside; *podes*, feet). The unarticulated lateral locomotive processes or "foot-tubercles" of many of the *Annelida*.

PARIETAL (Lat. *paries*, a wall). Connected with the walls of a cavity or of the body.

PARIETOSPLANCHNIC (Lat. *paries;* Gr. *splagchna*, viscera). Applied to one of the pairs of nerve-ganglia ("visceral" ganglia) in the *Mollusca*, as supplying filaments to the walls of the body and to the viscera.

PARTHENOGENESIS (Gr. *parthenos*, a virgin; *genesis*, birth). The production of new individuals from unfertilised ova, and therefore without the intervention of a male.

PATAGIUM (Lat. the border of a dress). Applied to the expansion of the integument by which Bats, Flying Squirrels, and other animals support themselves in the air.

PATELLA. The knee-cap or knee-pan. A sesamoid bone developed in the tendon of insertion of the great extensor muscles of the thigh.

PAUROPODA (Gr. *pauros*, little; *podes*, feet). An order of *Myriopoda*.

PECTEN (Lat. a comb). A peculiar fold of the choroid coat of the eye of Birds, which is continued obliquely through the vitreous humour to the lens.

PECTINATE (Lat. *pecten*, a comb). Comb-like.

PECTINIBRANCHIATA (Lat. *pecten;* Gr. *bragchia*, gill). Applied to certain of the Gastropods, from their comb-like gills.

PECTORAL (Lat. *pectus*, chest). Connected with, or placed upon, the chest.

PEDAL (Lat. *pes*, the foot). Connected with the foot of any animal. Applied more particularly to structures connected with the "foot" of Molluscs.

PEDICEL (Lat. dim. of *pes*, foot). A small stem or stalk. Applied in a restricted sense to the "tube-feet" of Echinoderms.

PEDICELLARIÆ (Lat. *pedicellus*, a louse). Certain singular appendages found in many *Echinoderms*, attached to the surface of the body, and resembling a little beak or forceps supported on a stalk.

PEDICLE (Lat. dim. of *pes*, the foot). A little stem.

PEDIPALPI (Lat. *pes*, foot; *palpo*, I feel). The order of *Arachnida* comprising the Scorpions. Sometimes used as a name for the maxillary palpi of the *Arachnida* generally.

PEDUNCLE (Lat. *pedunculus*, a stem or stalk). In a restricted sense applied to the muscular process by which certain *Brachiopods* are attached, and to the stem which bears the body (capitulum) in Barnacles.

PEDUNCULATE. Possessing a peduncle.

PELAGIC (Gr. *pelagos*, sea). Inhabiting the open ocean.

PELECYPODA (Gr. *pelekus*, an axe; *podes*, feet). A name often applied to the *Lamellibranchiata*, on account of many of them having a hatchet-shaped or sickle-shaped foot.

PELMATOZOA (Gr. *pelma*, stalk; *zoa*, animals). Applied as a collective term to indicate the Crinoids, Cystoids, and Blastoids, as opposed to the other Echinoderms (*Echinozoa*).

PELVIC. Connected with the pelvis, or with the hind-limbs generally.

PELVIS (Lat. a basin). Applied to the basin-shaped structure formed by the union of the two pelvic arches with the sacrum in the higher Vertebrates.

PERENNIBRANCHIATE (Lat. *perennis*, perpetual; Gr. *bragchia*, gill). Applied to Amphibians which retain the gills throughout life.

PERGAMENTACEOUS (Lat. *pergamena*, parchment). Of the texture of parchment.

PERICARDIUM (Gr. *peri*, around; *kardia*, heart). The serous membrane in which the heart is contained.

PERIDERM (Gr. *peri*, around; and *derma*, skin). The hard cuticular layer which is developed by the cœnosarc of certain of the *Hydrozoa*.

PERIGASTRIC (Gr. *peri*, around; and *gaster*, stomach). The perigastric space is the cavity which surrounds the stomach and other viscera, corresponding to the abdominal cavity of the higher animals.

PERIOSTRACUM (Gr. *peri*; and *ostrakon*, shell). The layer of epidermis which covers the shell in most of the *Mollusca*.

PERIPROCT (Gr. *peri*, around; *prōktos*, anus). The calcareous membrane surrounding the anus in the Sea-urchins.

PERISARC (Gr. *peri*, around; *sarx*, flesh). Employed by Prof. Allman as a general term for the chitinous envelope secreted by many of the *Hydrozoa*.

PERISOME (Gr. *peri*; and *soma*, body). The coriaceous or calcareous integument of the *Echinodermata*.

PERISSODACTYLA (Gr. *perissos*, uneven; *daktulos*, finger). Applied to those Hoofed Quadrupeds (*Ungulata*) in which the feet have an uneven number of toes.

PERISTOME (Gr. *peri*; and *stoma*, mouth). The space which intervenes between the mouth and the margin of the calyx in *Vorticella*; also the space between the mouth and the tentacles in a Sea-anemone (*Actinia*); also the lip or margin of the mouth of a univalve shell.

PERIVISCERAL (Gr. *peri*; and Lat. *viscera*, the internal organs). Applied to the space surrounding the viscera.

PES (Lat. foot). Applied in a restricted sense to the hind-feet of Vertebrates.

PETALOID. Shaped like the petals of a flower.

PHALANGES (Gr. *phalanx*, a row). The small bones composing the digits of the higher *Vertebrata*.

PHARYNGOBRANCHII (Gr. *pharugx*, pharynx; *bragchia*, gill). The order of Fishes comprising only the Lancelet.

PHARYNX. The dilated commencement of the gullet.

PHRAGMACONE (Gr. *phragma*, a partition; and *kōnos*, a cone). The chambered portion of the internal shell of a *Belemnite*.

PHYLACTOLÆMATA (Gr. *phulasso*, I guard; and *laimos*, throat). The division of *Polyzoa* in which the mouth is provided with the arched valvular process known as the "epistome."

PHYLLOCYSTS (Gr. *phullon*, leaf; and *kustis*, a cyst). The cavities in the interior of the "hydrophyllia" of certain of the Oceanic *Hydrozoa*.

PHYLLOPODA (Gr. *phullon*, leaf; and *pous*, foot). An order of *Crustacea*.

PHYLOGENESIS (Gr. *phulon*, race; *genesis*, origin). The development of the *species* or *race*, as opposed to that of the *individual*.

PHYOGEMMARIA (Gr. *phuo*, I produce; and Lat. *gemma*, bud). The small gonoblastidia of *Velella*, one of the *Physophoridæ*.

PHYSOPHORIDÆ (Gr. *phusa*, bellows or air-bladder; and *phero*, I carry). An order of Oceanic *Hydrozoa*.

PHYTOID (Gr. *phuton*, a plant; and *eidos*, form). Plant-like.

PHYTOPHAGOUS (Gr. *phuton*, a plant; and *phago*, I eat). Plant-eating, or herbivorous.

PINNATE (Lat. *pinna*, a feather). Feather-shaped, or possessing lateral processes.

PINNIGRADA (Lat. *pinna*, a feather; *gradior*, I walk). The group of *Carnivora*, comprising the Seals and Walruses, adapted for an aquatic life. Often called *Pinnipedia*.

PINNULÆ (Lat. dim. of *pinna*). The lateral processes of the arms of *Crinoids*. Slender lateral processes of any kind.

PISCES (Lat. *piscis*, a fish). The class of Vertebrates comprising the Fishes.

PLACENTA (Lat. a cake). The "after-birth," or the organ by which a vascular connection is established in the higher *Mammalia* between the mother and the fœtus.

PLACENTAL. Possessing a placenta, or connected with the placenta.

PLACOID (Gr. *plax*, a plate; *eidos*, form). Applied to the irregular bony plates, grains, or spines which are found in the skin of various fishes (*Elasmobranchii*).

PLAGIOSTOMI (Gr. *plagios*, transverse; *stoma*, mouth). The Sharks and Rays, in which the mouth is transverse, and is placed on the under surface of the head.

PLANARIDA (Gr. *planē*, wandering). A sub-order of the *Turbellaria*.

PLANTIGRADE (Lat. *planta*, the sole of the foot; *gradior*, I walk). Applying the sole of the foot to the ground in walking.

PLANULA (Lat. *planus*, flat). A form of embryo in various groups of Invertebrates, consisting of two layers of cells without a central segmentation-cavity.

PLASMODIUM (Gr. *plasma*, something moulded; *eidos*, form). The protoplasmic network or aggregate formed by the more or less complete coalescence of a number of cytodes.

PLASTRON. The lower or ventral portion of the bony case of the Chelonians.

PLATYELMIA (Gr. *platus*, broad; and *helmins*, an intestinal worm). The division of *Scolecida* comprising the Tape-worms, &c.

PLATYRHINA (Gr. *platus*, broad; *rhines*, nostrils). The South American Monkeys, characterised by their flat noses, with a wide septum narium, and having the nostrils placed far apart.

PLEURA (Gr. the side). The serous membrane covering the lung in the air-breathing Vertebrates.

PLEURODONT (Gr. *pleuron*, side; *odous*, tooth). Applied to the teeth of Lizards which are anchylosed with the inner margin of the alveolar border of the jaw.

PLEURON or PLEURA (Gr. *pleuron*, side, or rib). The lateral extension of the shell of the Crustacean segment at the point where the sternum and tergum join.

PLUTEUS (Lat. a pent-house). The larval form of the *Echinoidea*.

PNEUMATIC (Gr. *pneuma*, air). Filled with air.

PNEUMATOCYST (Gr. *pneuma*, air; and *kustis*, cyst). The air-sac or float of certain of the Oceanic *Hydrozoa* (*Physophoridæ*).

PNEUMATOPHORE (Gr. *pneuma*, air; and *phero*, I carry). The proximal dilatation of the cœnosarc in the *Physophoridæ* which surrounds the pneumatocyst.

PNEUMOSKELETON (Gr. *pneuma*; and *skeletos*, dry). The hard structures which are connected with the breathing organs (*e.g.*, the shell of Molluscs).

PODOPHTHALMATA (Gr. *pous*, foot ; and *ophthalmos*, eye). The division of Crustacea in which the eyes are borne at the end of long foot-stalks.
PODOSOMATA (Gr. *pous*, foot ; *soma*, body). An order of *Arachnida*.
POEPHAGA (Gr. *poē*, grass ; *phago*, I eat). A group of the Marsupials.
POLLEX (Lat. the thumb). The innermost of the five normal digits of the anterior limb of the higher Vertebrates. In man, the thumb.
POLYCHÆTA (Gr. *polus*, many ; *chaitē*, bristle). A name often applied to the Tubicolar and Errant Annelides to distinguish them collectively from the *Oligochæta* (Earth-worms, &c.)
POLYCYSTINA (Gr. *polus*, many ; and *kustis*, a cyst). An order of *Protozoa*, with foraminated siliceous shells.
POLYGASTRICA (Gr. *polus ;* and *gaster*, stomach). The name applied by Ehrenberg to the *Infusoria*, under the belief that they possessed many stomachs.
POLYPARY. The hard chitinous covering secreted by many of the *Hydrozoa*.
POLYPE (Gr. *polus*, many ; *pous*, foot). Restricted to the single individual of a simple *Actinozoön*, such as a Sea-anemone, or to the separate zoöids of a compound *Actinozoön*. Often applied indiscriminately to any of the *Cœlenterata*, or even to the *Polyzoa*.
POLYPIDE. The separate zoöid of a *Polyzoön*.
POLYPIDOM. The dermal system of a colony of a *Hydrozoön* or *Polyzoön*.
POLYPITE. The separate zoöid of a *Hydrozoön*.
POLYSTOME (Gr. *polus*, many ; and *stoma*, mouth). Having many mouths ; applied to the *Acinetæ* amongst the *Protozoa*.
POLYTHALAMOUS (Gr. *polus ;* and *thalamos*, chamber). Having many chambers—applied to the shells of *Foraminifera* and *Cephalopoda*.
POLYTROCHAL (Gr. *polus*, many ; *trochos*, wheel). An epithet applied to those larvæ of Annelides and other Invertebrates, in which there are successively-disposed circlets of cilia.
POLYZOA (Gr. *polus ;* and *zoön*, animal). A division of the *Molluscoida*, comprising compound animals, such as the Sea-mat. Sometimes called *Bryozoa*.
POLYZOARIUM. The dermal system of the colony of a *Polyzoön* (=Polypidom).
PORCELLANOUS. Of the texture of porcelain.
PORIFERA (Lat. *porus*, a pore ; and *fero*, I carry). The division of the Sponges.
POST-ABDOMEN. That portion of the "abdomen" of *Crustacea*, *Arachnida*, and *Myriopoda* which lies behind the segments corresponding with the abdomen of Insects.
POST-ANAL. Situated behind the anus.
POST-ŒSOPHAGEAL. Situated behind the gullet.
POST-ORAL. Situated behind the mouth.
PRÆMAXILLÆ. The bones which form the front of the upper jaw in Vertebrates, and normally carry in Mammals the upper incisor teeth. In man, the præmaxillæ are anchylosed with each other and with the maxillæ.
PRÆMOLARS (Lat. *præ*, before ; *molares*, the grinders). The molar teeth of Mammals which succeed the molars of the milk-set of teeth. In man, the bicuspid teeth.
PRÆ-ŒSOPHAGEAL. Situated in front of the gullet.
PRÆ-STERNUM. The anterior portion of the breast-bone, corresponding with the *manubrium sterni* of human anatomy, and extending as far as the point of articulation of the second rib.
PRIMATES (Lat. *primas*, chief or noble). The order of Mammals including Man and the Monkeys. Linnæus included the Bats also under this name.
PROBOSCIDEA (Lat. *proboscis*, the snout). The order of Mammals comprising the Elephants.
PROBOSCIS (Lat. or Gr. the snout). Applied to the spiral trunk of *Lepidopterous Insects*, to the projecting mouth of certain *Crinoids*, and to the central polypite in the *Medusæ*.
PROCŒLOUS (Gr. *pro*, before ; *koilos*, hollow). Applied to vertebræ, the bodies of which are hollow or concave in front.

PROCTUCHOUS (Gr. *prōktos*, anus; *echo*, I have). Possessing an anal aperture.

PROGLOTTIS (Gr. for the tip of the tongue). The generative segment or joint of a Tape-worm.

PRO-LEGS. The false abdominal feet of Caterpillars.

PRONATION (Lat. *pronus*, lying on the face, prone). The act of turning the palm of the hand downwards.

PROPODIUM (Gr. *pro*, before; *pous*, foot). The anterior part of the foot in Molluscs.

PROSCOLEX (Gr. *pro*, before; *scolex*, worm). The first embryonic stage of a Tape-worm.

PROSOBRANCHIATA (Gr. *prosō*, in advance of; *bragchia*, a gill). A division of Gastropodous Molluscs in which the gills are situated in advance of the heart.

PROSOMA (Gr. *pro*, before; *soma*, body). The anterior part of the body.

PROTHORAX (Gr. *pro;* and *thorax*, chest). The anterior ring of the thorax of insects.

PROTOPHYTA (Gr. *protos*, first; and *phuton*, plant). The lowest division of plants.

PROTOPLASM (Gr. *protos;* and *plasso*, I mould). The elementary basis of organised tissues, or the elementary form of living matter.

PROTOPODITE (Gr. *protos*, first; and *pous*, foot). The basal segment of the typical limb of a *Crustacean.*

PROTOZOA (Gr. *protos;* and *zoön*, animal). The lowest division of the animal kingdom.

PROVENTRICULUS (Lat. *pro*, in front of; *ventriculus*, dim. of *venter*, belly). The cardiac portion of the stomach of birds.

PROXIMAL (Lat. *proximus*, next). The slowly-growing, comparatively-fixed extremity of a limb or of an organism.

PSALTERIUM (Lat. a stringed instrument). The third stomach of Ruminants. (*See* Omasum.)

PSEUDEMBRYO (Gr. *pseudos*, falsity; *embruon*, embryo). The larval form of an *Echinoderm.*

PSEUDOBRANCHIA (Gr. *pseudos*, falsity; *bragchia*, gill). A supplementary gill found in certain fishes, which receives arterialised blood only, and does not, therefore, assist in respiration.

PSEUDOHÆMAL (Gr. *pseudos*, falsity; and *haima*, blood). Applied to the vascular system of *Annelida.*

PSEUDOHEARTS. The tubular excretory organs (nephridia) of *Brachiopoda*, originally considered to be hearts.

PSEUDONAVICELLÆ (Gr. *pseudos*, false; and *Navicula*, a genus of Diatoms). The embryonic forms of the *Gregarinidæ*, so called from their resemblance in shape to the *Navicula.*

PSEUDOPODIA (Gr. *pseudos;* and *pous*, foot). The extensions of the body-substance which are put forth at will by the *Rhizopoda*, or by any wall-less mass of protoplasm, and which serve for locomotion and prehension.

PSEUDOVA (Gr. *pseudos;* Lat. *ovum*, egg). The egg-like bodies from which the young of the viviparous *Aphis* are produced.

PTEROPODA (Gr. *pteron*, wing; and *pous*, foot). A class of the *Mollusca* which swim by means of fins attached near the head.

PTEROSAURIA (Gr. *pteron*, wing; *saura*, lizard). An extinct order of reptiles.

PUBIS (Lat. *pubes*, hair). The share-bone; one of the bones which enter into the composition of the pelvic arch of Vertebrates.

PULMOGASTROPODA (=Pulmonifera).

PULMONATE. Possessing lungs.

PULMONIFERA (Lat. *pulmo*, a lung; and *fero*, I carry). The division of Gastropodous *Mollusca* which breathe by means of a pulmonary chamber.

PUPA (Lat. a doll). The stage of an insect immediately preceding its appearance in a perfect condition. In the pupa-stage it is usually quiescent—when it is often called a "chrysalis"; but it is sometimes active—when it is often called a "nymph."

PYGAL (Gr. *pugé*, the rump). Connected with the hinder end of the trunk.

PYGIDIUM (Gr. *pugidion*, dim. of *pugê*). The anchylosed somites which form the caudal shield of certain Crustaceans.
PYLORUS (Gr. *puloros*, a gatekeeper). The valvular aperture between the stomach and the intestine.
PYRIFORM (Lat. *pyrus*, a pear; and *forma*, form). Pear-shaped.

QUADRUMANA (Lat. *quatuor*, four; *manus*, hand). Sometimes used as an ordinal designation for the Monkeys.

RADIATA (Lat. *radius*, a ray). Formerly applied to a large number of animals which are now placed in separate sub-kingdoms (*e.g.*, the *Cœlenterata*, the *Echinodermata*, the *Infusoria*, &c.).
RADIOLARIA (Lat. *radius*, a ray). A division of *Protozoa*.
RADIUS (Lat. a spoke or ray). The innermost of the two bones of the fore-arm of the higher Vertebrates.
RADULA (Lat. *radula*, a scraping-iron). The toothed lingual strap or "tongue" of the Gastropods, Pteropods, and Cephalopods.
RAMUS (Lat. a branch). Applied in a general sense to a branch-like division of any structure. Each half of the mandible of Vertebrates is the "ramus."
RAPTORES (Lat. *rapto*, I plunder). The Birds of Prey.
RASORES (Lat. *rado*, I scratch). A name formerly given to the Gallinaceous Birds.
RATITÆ (Lat. *ratis*, a raft). The sub-class of Birds comprising the Ostrich, &c. So called from the raft-like form of the sternum.
RECTRICES (Lat. *rectrix*, a directress). The quill-feathers of the tail of Birds.
RECTUM (Lat. *rectus*, straight). The terminal portion of the intestinal canal.
REMIGES (Lat. *remex*, a rower). The quill-feathers of the wing of Birds.
REPTILIA (Lat. *repto*, I crawl). The class of the *Vertebrata* comprising the Tortoises, Snakes, Lizards, Crocodiles, &c.
RETICULARIA or RETICULOSA (Lat. *reticulum*, a net). A designation for those *Protozoa*, such as the *Foraminifera*, in which the pseudopodia run into one another and form a network.
RETICULUM (Lat. a net). The second division of the complex stomach of Ruminants, often called the "honeycomb-bag."
REVERSED. Applied to spiral Univalves, in which the direction of the spiral is the reverse of the normal—*i.e.*, *sinistral*.
RHABDOPHORA (Gr. *rhabdos*, a rod; and *phero*, I carry). Employed by Prof. Allman as a name for the Graptolites, in consequence of their commonly possessing a chitinous rod or axis supporting the perisarc.
RHIZOPHAGA (Gr. *rhiza*, root; *phago*, I eat). A group of the Marsupials.
RHIZOPODA (Gr. *rhiza*, a root; and *pous*, foot). The division of *Protozoa* comprising all those which are capable of emitting pseudopodia.
RHOPALOCERA (Gr. *rhopalon*, club; *keras*, horn). A name given to the Butterflies among the Lepidoptera in allusion to the fact that the antennæ are clubbed at the end.
RODENTIA (Lat. *rodo*, I gnaw). An order of the Mammals; often called *Glires* (Lat. *glis*, a dormouse).
ROSTRUM (Lat. *rostrum*, beak). The "beak" or suctorial organ formed by the appendages of the mouth in certain insects. A snout-like projection of any kind.
ROTATORIA (=Rotifera).
ROTIFERA (Lat. *rota*, wheel; and *fero*, I carry). A class of the *Scolecida* characterised by a ciliated "trochal disc."
RUGOSA (Lat. *rugosus*, wrinkled). An order of Corals.
RUMEN (Lat. the throat). The first cavity of the complex stomach of Ruminants; often called the "paunch."
RUMINANTIA (Lat. *ruminor*, I chew the cud). The group of Hoofed Quadrupeds (*Ungulata*) which "ruminate" or chew the cud.

SACRUM (Lat. *os sacrum*, the sacred bone). The vertebræ (usually anchylosed)

with which the pelvic arches unite. Sometimes there is only a single sacral vertebra.

SAND-CANAL (=STONE-CANAL). A tube connected with the circular ring of the ambulacral system in the Echinoderms, and usually communicating with the exterior by the madreporite.

SARCODE (Gr. *sarx*, flesh; *eidos*, form). A name often used to designate the protoplasmic substance of which the bodies of the *Protozoa* are made up.

SARCODINA. Employed by Bütschli as a general term to include the *Monera, Amœbea, Foraminifera, Radiolaria*, and *Heliozoa*.

SAURIA (Gr. *saura*, a lizard). Any lizard-like Reptile is often spoken of as a "Saurian," but the term is sometimes restricted to the Crocodiles and Lizards.

SAUROPSIDA (Gr. *saura*; and *opsis*, appearance). The name given by Huxley to the two classes of the Birds and Reptiles collectively.

SAUROPTERYGIA (Gr. *saura*; *pterux*, wing). An extinct order of Reptiles, called by Huxley *Plesiosauria*, from the typical genus *Plesiosaurus*.

SAURURÆ (Gr. *saura*; *oura*, tail). The extinct order of Birds comprising only the *Archæopteryx*.

SCANSORES (Lat. *scando*, I climb). A term often employed in an ordinal sense to indicate the Parrots, Woodpeckers, &c., in which the foot is specially adapted for climbing.

SCAPHOGNATHITE (Gr. *skaphos*, boat; and *gnathos*, jaw). The boat-shaped appendage (epipodite) of the second pair of maxillæ in the Lobster, the function of which is to spoon out the water from the branchial chamber.

SCAPULA (Lat. for shoulder-blade). The shoulder-blade of the pectoral arch of Vertebrates.

SCLERENCHYMA (Gr. *skleros*, hard; and *enchuma*, tissue). The calcareous tissue of which a coral is composed.

SCLERITES (Gr. *skleros*). The calcareous spicules which are scattered in the soft tissues of certain *Actinozoa*.

SCLEROBASIC (Gr. *skleros*, hard; *basis*, pedestal). Applied to the corallum which is produced by the cœnosarc in certain *Actinozoa* (*e.g.*, Red Coral), and which forms a solid axis which is invested by the soft parts of the animal. It is called "foot-secretion" by Dana.

SCLERODERMIC (Gr. *skleros*; and *derma*, skin). Applied to the corallum which is deposited between the tissues of certain *Actinozoa*, and is called "tissue-secretion" by Dana.

SCLEROTIC (Gr. *skleros*, hard). The outer dense fibrous coat of the eye.

SCOLECIDA (Gr. *skolēx*, worm). A division of the *Annulosa*, including the *Entozoa*, *Rotifera*, &c.

SCOLEX (Gr. *skolēx*). An embryonic stage of a Tape-worm, formerly known as a "Cystic worm."

SCUTA (Lat. *scutum*, a shield). Applied to any shield-like plates; especially to those which are developed in the integument of many Reptiles.

SELACHIA or SELACHII (Gr. *selachos*, a cartilaginous fish, probably a shark). The sub-order of *Elasmobranchii* comprising the Sharks and Dog-fishes.

SEPIOSTAIRE. The internal shell of the *Sepia*, commonly known as the "cuttle-bone."

SEPTA. Partitions.

SERPENTIFORM. Resembling a serpent in shape.

SERTULARIDA (Lat. *sertum*, a wreath). An order of *Hydrozoa*.

SESAMOID (Gr. *sēsamon*, the seed of the *Sesamum*; *eidos*, form). A "sesamoid" bone is an ossification formed in the tendon of a muscle, and not belonging to the proper skeleton.

SESSILE (Lat. *sedeo*, I sit). Not supported upon a stalk or peduncle; attached by a base.

SETÆ (Lat. bristles). Bristles, or long stiff hairs.

SETIFEROUS. Supporting bristles.

SETIGEROUS (=Setiferous).

SETOSE. Bristly.

SILICEOUS (Lat. *silex*, flint). Composed of flint.

SINISTRAL (Lat. *sinistra*, the left hand). Left-handed; applied to the direction of the spiral in certain shells, which are said to be "reversed."
SINUS (Lat. *sinus*, a bay). A dilated vein or blood-receptacle. An indentation or curvature of a line, &c.
SIPHON (Gr. *siphon*, a tube). Applied to the respiratory tubes in the *Mollusca;* also to other tubes of different functions.
SIPHONOPHORA (Gr. *siphon;* and *phero*, I carry). A division of the *Hydrozoa*, comprising the Oceanic forms (*Calycophoridæ* and *Physophoridæ*).
SIPHONOSTOMATA (Gr. *siphon;* and *stoma*, mouth). The division of *Gastropodous Molluscs*, in which the aperture of the shell is not "entire," but possesses a notch or tube for the emission of the respiratory siphon.
SIPHUNCLE (Lat. *siphunculus*, a little tube). The tube which connects together the various chambers of the shell of certain *Cephalopoda* (*e.g.*, the Pearly Nautilus).
SIPUNCULOIDEA (Lat. *siphunculus*, a little siphon). A name sometimes given to the *Gephyrea.*
SIRENIA (Gr. *seiren*, a mermaid). The order of *Mammalia* comprising the Dugongs and Manatees.
SOLIDUNGULA (Lat. *solidus*, solid; *ungula*, a hoof). The group of Hoofed Quadrupeds, comprising the Horse, Ass, and Zebra, in which each foot, in the living forms, has only a single solid hoof. Often called *Solipedia.*
SOMATIC (Gr. *soma*, body). Connected with the body.
SOMATOCYST (Gr. *soma;* and *kustis*, a cyst). A peculiar cavity in the cœnosarc of the *Calycophoridæ* (*Hydrozoa*).
SOMITE (Gr. *soma*). A single segment in the body of an Articulate animal.
SPERMARIUM. The testis, or organ in which spermatozoa are produced.
SPERMATOPHORES (Gr. *sperma*, seed; *phero*, I carry). The variously shaped packages or capsules in which the spermatozoa are aggregated or enclosed in many Invertebrate animals.
SPERMATOZOA (Gr. *sperma*, seed; and *zoön*, animal). The microscopic filaments which form the essential generative element of the male.
SPHÆRIDIA (Gr. *sphairidion*, a little ball or sphere). Minute, stalked appendages, with button-shaped heads, carried by most living Sea-urchins, and supposed to be organs of sense.
SPICULA (Lat. *spiculum*, a point). Pointed, needle-shaped bodies.
SPINNERETS. The organs by means of which Spiders and Caterpillars spin threads.
SPIRACLES (Lat. *spiro*, I breathe). The breathing-pores or apertures of the breathing-tubes (tracheæ) of Insects. Also the single nostril of the Hag-fishes, the "blow-hole" of Cetaceans, &c.
SPLANCHNOSKELETON (Gr. *splagchna*, viscera; *skeletos*, dry). The hard structures occasionally developed in connection with the internal organs or viscera.
SPONGIDA (Gr. *spoggos*, a sponge). The Sponges.
SPORES (Gr. *spora*, seed). Germs, usually of plants; in a restricted sense, the reproductive "gemmules" of certain sponges.
SPOROSACS (Gr. *spora*, seed; and *sakkos*, a bag). The simple generative buds of certain *Hydrozoa*, in which the medusoid structure is not developed.
SQUAMATA (Lat. *squama*, a scale). The division of reptiles comprising the *Ophidia* and *Lacertilia*, in which the integument develops horny scales, but there are no dermal ossifications.
STATOBLASTS (Gr. *statos*, stationary; *blastos*, bud). Certain reproductive buds developed in the interior of *Polyzoa*, but not liberated until the death of the parent organism.
STEGANOPHTHALMATA (Gr. *steganos*, covered; and *ophthalmos*, the eye). Applied by Edward Forbes to the Acraspedote *Medusæ*, in which the sense-organs ("marginal bodies") are concealed from view.
STELLERIDA (Lat. *stella*, a star). Sometimes used to designate the order of the Star-fishes, or as a collective name for the Asteroids and Ophiuroids.
STELLIFORM. Star-shaped.
STEMMATA (Gr. *stemma*, garland). The simple eyes, or "ocelli," of certain animals, such as Insects, Spiders, and Crustacea.

STERNUM (Gr. *sternon*). The breast-bone. By analogy, the inferior arch of the segment of an Arthropod.
STIGMATA. The breathing-pores in *Insects*, *Myriopods*, and *Arachnida*.
STOLON (Gr. *stolos*, a sending forth). Offshoots.—The connecting-processes of sarcode in *Foraminifera;* the connecting-tube in the social *Ascidians;* the processes sent out by the cœnosarc of certain *Actinozoa*.
STOMATODE (Gr. *stoma*, mouth). Possessing a mouth.
STOMATOPODA (Gr. *stoma*, mouth; *podes*, feet). The order of Crustaceans comprising the Locust-shrimps.
STREPSIPTERA (Gr. *strepho*, I twist; *pteron*, wing). An order of Insects in which the anterior wings are represented by twisted rudiments.
STREPSIRHINA (Gr. *strepho*, I twist; *rhines*, nostrils). A name given by Owen to the Lemurs and their allies (*Lemuroidea*), on account of their twisted nostrils.
STROBILA (Gr. *strobilos*, a top, or fir-cone). The adult Tape-worm, with its generative segments or proglottides; also applied to one of the stages in the life-history of the *Lucernarida*.
STYLIFORM (Lat. *stylus*, a pointed instrument; *forma*, form). Pointed in shape.
SUB-CALCAREOUS. Somewhat calcareous.
SUB-CENTRAL. Nearly central, but not quite.
SUB-PEDUNCULATE. Supported upon a very short stem.
SUB-SESSILE. Nearly sessile, or almost without a stalk.
SUPINATION (Lat. *supinus*, lying with the face upwards). The act of turning the hand with the palm upwards.
SUTURE (Lat. *suo*, I sew). The line of junction of two parts which are immovably connected together. Applied to the line where the whorls of a univalve shell join one another; also to the lines made upon the exterior of the shell of a chambered *Cephalopod* by the margins of the septa.
SWIMMERETS. The limbs of *Crustacea* which are adapted for swimming.
SYMPHYSIS (Gr. *sumphusis*, a growing together). Union of two bones in which there is no motion, or but a very limited amount.
SYNAPTICULÆ (Gr. *sunapto*, I fasten together). Transverse props sometimes found in corals, extending across the loculi like the bars of a grate.
SYNTHETIC (Gr. *sun*, together; *tithemi*, I place). An animal is said to be a "synthetic type" when it combines in itself the structural characters of two different groups.
SYRINX (Gr. *surigx*, a pipe). The lower larynx of Birds.
SYSTOLÉ (Gr. *sustello*, I contract). Applied to the contraction of any contractile cavity, especially the heart.

TABULÆ (Lat. *tabula*, a tablet). Horizontal plates or floors found in some Corals, extending across the cavity of the "theca" from side to side.
TACTILE (Lat. *tango*, I touch). Connected with the sense of touch.
TÆNIADA (Gr. *tainia*, a ribbon). The division of *Scolecida* comprising the Tape-worms.
TÆNIOID (Gr. *tainia;* and *eidos*, form). Ribbon-shaped, like a Tape-worm.
TARSO-METATARSUS. The single bone in the leg of Birds produced by the union and anchylosis of the lower or distal portion of the tarsus with the second, third, and fourth metatarsals.
TARSUS (Gr. *tarsos*, the flat of the foot). The small bones which form the ankle (or "instep" of man), and which correspond with the wrist (*carpus*) of the anterior limb.
TECTIBRANCHIATA (Lat. *tectus*, covered; and Gr. *bragchia*, gills). A division of *Opisthobranchiate Gastropoda* in which the gills are protected by the mantle.
TEGUMENTARY (Lat. *tegumentum*, a covering). Connected with the integument or skin.
TELEOSTEI (Gr. *teleios*, perfect; *osteon*, bone). The order of the "Bony" Fishes.
TELSON (Gr. a limit). The last joint in the abdomen of *Crustacea;* vari-

ously regarded as a segment without appendages, or as an azygous appendage.

TENUIROSTRAL (Lat. *tenuis*, slender; *rostrum*, beak). Applied to the long, slender, and pointed beak of such birds as Humming-birds.

TERGAL (Lat. *tergum*, back). Situated on, or belonging to, the back.

TERGUM (Lat. for back). The dorsal arc of the somite of an Arthropod.

TERRICOLA (Lat. *terra*, earth; and *colo*, I inhabit). Employed occasionally to designate the Earth-worms (*Lumbricidæ*).

TEST (Lat. *testa*, shell). The shell of *Mollusca*, which are for this reason sometimes called "*Testacea*"; also, the calcareous case of *Echinoderms;* also, the thick leathery outer tunic in the *Tunicata;* also the shell of the *Foraminifera.*

TESTACEOUS. Provided with a shell or hard covering.

TESTIS (Lat. *testis*, the testicle). The organ in the male animal which produces the generative elements (spermatozoa).

TETRABRANCHIATA (Gr. *tetra*, four; *bragchia*, gills). The order of *Cephalopoda* characterised by the possession of four gills.

THALASSICOLLIDA (Gr. *thalassa*, sea; *kolla*, glue). A division of *Radiolaria.*

THECA (Gr. *thekê*, a sheath). A sheath or receptacle.

THECODONT (Gr. *thekê*, a sheath; *odous*, tooth). Applied to that form of dentition in which the teeth are sunk in distinct sockets in the jaw.

THECOSOMATA (Gr. *thekê*, a case; *soma*, body). The division of Pteropods in which the body is protected by an external shell.

THORAX (Gr. *thorax*, the breast, or a breast-plate). In the higher animals, the thorax is the region of the body which intervenes between the abdomen and the head.

THREAD-CELLS. (*See* Cnidæ.)

THYSANURA (Gr. *thusanoi*, fringes; and *oura*, tail). An order of Apterous Insects.

TIBIA (Lat. a flute). The shin-bone, being the innermost of the two bones of the leg, and corresponding with the *radius* in the anterior extremity.

TOTIPALMATÆ (Lat. *totus*, whole; *palma*, the palm of the hand). A group of Swimming Birds in which the hallux is united to the other toes by membrane, so that the feet are completely webbed.

TOXODONTIA (Gr. *toxon*, bow; *odous*, tooth). An extinct order of Mammals.

TRACHEA (Gr. *tracheia*, the rough windpipe). The tube which conveys air to the lungs in the air-breathing Vertebrates.

TRACHEÆ. The breathing-tubes of Insects and other Articulate animals.

TRACHEARIA. The division of *Arachnida* which breathe by means of tracheæ.

TREMATODA (Gr. *trēma*, a pore). An order of *Scolecida.*

TRICHOCYSTS (Gr. *thrix*, hair; and *kustis*, a cyst). Peculiar rod-like bodies found in certain *Infusoria*, and presenting certain likenesses to the "thread-cells" of *Cœlenterata.*

TRILOBITA (Gr. *treis*, three; *lobos*, a lobe). An extinct order of *Crustacea.*

TRITOZOÖID (Gr. *tritos*, third; *zoön*, animal; and *eidos*, form). The zoöid produced by a deuterozoöid—that is to say, a zoöid of the third generation.

TROCHAL (Gr. *trochos*, a wheel). Wheel-shaped; applied to the ciliated disc of the *Rotifera.*

TROCHANTER (Gr. *trecho*, I run). A process of the upper part of the thigh-bone (*femur*) to which are attached the muscles which rotate the limb. There may be two, or even three, trochanters present. In Insects the second joint of the leg is called the trochanter.

TROCHOID (Gr. *trochos*, a wheel; and *eidos*, form). Conical with a flat base; applied to the shells of *Foraminifera* and *Univalve Molluscs.*

TROCHOSPHERE. A form of larva seen in Rotifers, Molluscs, many Worms, &c., in which there is a circlet of long cilia in front of the mouth, and often one or more post-oral rings of shorter cilia.

TROPHI (Gr. *trophos*, a nourisher). The parts of the mouths in Insects which are concerned in the acquisition and preparation of food. Often called "instrumenta cibaria."

TROPHOSOME (Gr. *trepho*, I nourish; and *soma*, body). Applied collectively to the assemblage of the nutritive zoöids of any *Hydrozoön*.
TRUNCATED (Lat. *trunco*, I shorten). Abruptly cut off; applied to univalve shells, the apex of which breaks off, so that the shell becomes "decollated."
TUBICOLA (Lat. *tuba*, a tube; and *colo*, I inhabit). The group of Chætopod Annelides in which the animals construct a tubular case in which they protect themselves.
TUBICOLOUS. Inhabiting a tube.
TUNICATA (Lat. *tunica*, a cloak). The Ascidians or "Sea-squirts," so called from their possession of a leathery external case or "test."
TURBELLARIA (Lat. *turbo*, I disturb). An order of *Scolecida*.
TURBINATED (Lat. *turbo*, a top). Top-shaped; conical with a round base.

ULNA (Gr. *olené*, the elbow). The outermost of the two bones of the fore-arm, corresponding with the *fibula* of the hind-limb.
UMBELLATE (Lat. *umbella*, a parasol). Forming an umbel—*i.e.*, a number of nearly equal *radii* all proceeding from one point.
UMBILICUS (Lat. for navel). The aperture seen at the base of the axis of certain univalve shells, which are then said to be "perforated" or "umbilicated." The navel.
UMBO (Lat. the boss of a shield). The beak of a bivalve shell.
UMBRELLA. The contractile disc of one of the Acraspedote Medusæ.
UNCINATE (Lat. *uncinus*, a hook). Provided with hooks or bent spines.
UNGUICULATE (Lat. *unguis*, nail). Furnished with claws.
UNGULATA (Lat. *ungula*, hoof). The order of *Mammals* comprising the Hoofed Quadrupeds.
UNGULATE. Furnished with expanded nails constituting hoofs.
UNILOCULAR (Lat. *unus*, one; and *loculus*, a little purse). Possessing a single cavity or chamber. Applied to the shells of *Foraminifera* and *Mollusca*.
UNIVALVE (Lat. *unus*, one; *valvæ*, folding-doors). A shell composed of a single piece or valve.
URODELA (Gr. *oura*, tail; *delos*, visible). The order of the tailed Amphibians (Newts, &c.)
UROSTYLE (Gr. *oura*, tail; *stulos*, pillar). The long spine formed by ossification of the sheath of the hinder end of the notochord in many Teleostean Fishes. Also the elongated "coccyx" of the Anourous Amphibians.
URTICATING-CELLS (Lat. *urtica*, a nettle). (*See* Cnidæ.)

VACUOLES (Lat. *vacuus*, empty). The little clear spaces which are seen in the protoplasm of the *Protozoa* generally, and which are for the most part merely temporary. When these spaces are formed round particles of ingested food, they are called "food-vacuoles."
VARICES (Lat. *varix*, a dilated vein). The ridges or spinose lines which mark the former position of the mouth in certain univalve shells.
VASCULAR (Lat. *vas*, a vessel). Connected with the circulatory system.
VELIGER (Lat. *velum*, a sail; *gero*, I carry). A name applied to the larvæ of many of the Molluscs, on account of their possessing ciliated lappets forming a "velum."
VELUM (Lat. a sail). The membrane which surrounds and partially closes the mouth of the "disc" of the Craspedote *Medusæ* or of medusiform gonophores.
VENTRAL (Lat. *venter*, the stomach). Relating to the inferior surface of the body.
VENTRICLE (Lat. dim. of *venter*, stomach). Applied to one of the cavities of the heart, which receives blood from the auricle.
VERMES (Lat. *vermis*, a worm). Sometimes employed at the present day as a common term for the Scolecids and the *Anarthropoda*.
VERMIFORM (Lat. *vermis*, worm; and *forma*, form). Worm-like.
VERTEBRA (Lat. *verto*, I turn). One of the bony or cartilaginous segments of the vertebral column or backbone.
VERTEBRATA (Lat. *vertebra*, a bone of the back, from *vertere*, to turn). The

division of the Animal Kingdom roughly characterised by the possession of a backbone.

VESICLE (Lat. *vesica*, a bladder). A little sac or cyst.

VIBRACULA (Lat. *vibro*, I shake). Long filamentous appendages found in many *Polyzoa*.

VIPERINA (Lat. *vipera*, a viper). A group of the Snakes.

VITREOUS (Lat. *vitrum*, glass). Glassy, transparent. The "vitreous" sponges are those with a skeleton of flint.

VIVIPAROUS (Lat. *vivus*, alive; and *pario*, I bring forth). Bringing forth young alive.

WHORL. The spiral turn of a univalve shell.

XIPHISTERNUM (Gr. *xiphos*, sword; *sternon*, breast-bone). The inferior or posterior segment of the sternum, corresponding with the "xiphoid cartilage" of human anatomy.

XIPHOSURA (Gr. *xiphos*, a sword; and *oura*, tail). An order of *Crustacea*, comprising the *Limuli* or King-crabs, characterised by their long sword-like tails.

XYLOPHAGOUS (Gr. *xulon*, wood; and *phago*, I eat). Eating wood, applied to certain *Mollusca*.

ZEUGLODONTIDÆ (Gr. *zeuglê*, a yoke; *odous*, a tooth). An extinct family of Cetaceans, in which the molar teeth are two-fanged, and look as if composed of two parts united by a neck.

ZOŒCIUM (Gr. *zoön*, animal; *oikos*, house). The "cell" or chamber in which the polypide of a Polyzoön is contained.

ZOÖID (Gr. *zoön*, animal; and *eidos*, like). The more or less completely independent organisms produced by gemmation or fission, whether these remain attached to one another or are detached and set free.

ZOOPHYTE (Gr. *zoön*, animal; *phuton*, plant). Loosely applied to many plant-like animals, such as Sponges, Corals, Sea-anemones, Sea-mats, &c.

ZOOSPORES (Gr. *zoön*, animal; and *spora*, seed). The ciliated locomotive germs of some of the lowest forms of plants (*Protophyta*).

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